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GRAIN FINISHING CULL BEEF COWS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled GRAIN FINISHING CULL BEEF COWS submitted by WILLIAM C. GRAHAM in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in ANIMAL PRODUCTION.

ABSTRACT

Two experiments were conducted to study the effect of cow age on the feedlot performance and carcass characteristics of cull range cows during realimentation.

In the first experiment, eighty-seven cull cows of three breed types (Hereford, beef composite and dairy composite) and three age groups (young, intermediate and mature) were used. Initially, one-third of the animals were killed as a control group. The remainder were allotted at randon to two pens per breed and fed for either 8 or 16 weeks. Average daily gain dropped from 1.80 kg/ day in the first 8 weeks to 1.13 kg/ day in the last 8 weeks ($p<.01$). Feed/ gain ratios increased from an average of 6.9 in the first feeding period to 12.8 in the second ($p<.01$). There were no differences among breeds in feedlot performance ($p>.05$). The data for carcass weight and rib eye area were adjusted to a constant carcass length. Age had a significant effect on carcass length ($p<.01$) and adjusted rib eye area ($p<.05$). The oldest group had a carcass length of 137 cm and an adjusted rib eye area of 56.7 cm^2 compared to 121 cm and 71.5 cm^2 for the youngest group. There were no other significant differences among breeds or age groups for fat thickness over the rib eye, carcass length, adjusted carcass weight or adjusted rib eye area.

In the second experiment, slaughter data were collected from 37 cull range cows of predominantly Angus breeding.

Twenty-nine of these cows were fed a high grain ration *ad libitum* for 8 weeks before slaughter. The cows represented two age groups: 3-4 years of age and ≥6 years of age, both groups having similar liveweight. Feed consumption was not significantly different between age groups. Young cows ate 12.56 kg DM/ head/ day; mature cows ate 12.48 kg DM/ head/ day. The young and mature cows gained 1.61 and 1.29 kg/ head/ day respectively ($p<.05$). Backfat measurements by ultrasonic probe at the 12th rib (7.5 cm off midline) on Day 1, ranged from 1 to 14 mm. This range had no apparent effect on subsequent feedlot performance. Carcass length measurements taken after slaughter were 133.5 (young) and 138.2 (mature, $p<.05$). Carcass weights, adjusted to a constant length and fat thickness were 346 kg (young) and 310 kg (mature, $p<.05$). There were no significant differences in rib eye areas or adjusted rib eye areas ($p>.05$). In the 9-10-11th rib joint, the young cows had as much muscle (3025 g) as the mature cows (2908 g), in spite of their lower bone weights (770 g and 856 g, $p<.01$). After adjusting to a constant bone and a constant fat weight, the values for muscle weight were significantly ($p<.05$) greater for the young cows.

In an additional experiment, tetracycline labeling was used to measure growth in length at the distal radius in 14 young cows. This growth was measured in the early stages of a grain feeding period and again during *ad libitum* intake. In 4 four year old cows, closure had already occurred in the

epiphyseal growth plate, so no linear growth occurred. In 5 two year old cows and 5 three year old cows there was no indication that grain feeding increased the rate of linear bone growth.

Overall, It was concluded that the youthful cows were superior to the mature cows in terms of feedlot performance and carcass quality. An economic analysis for 1980 showed that the potential profit from grain finishing cull cows was highest for those cows five years of age or less.

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I. INTRODUCTION

A. THE ROLE OF COW BEEF IN MEAT PRODUCTION

The amount of "cow beef", or beef from females that have already gone through at least one pregnancy, is determined by the maternal productivity of the beef herd. Unlike litter bearing animals such as swine, each beef cow normally only produces one offspring or less per year. As long as the average lifetime production for beef cows is less than seven calves weaned, more than 15% of the cattle slaughtered will be cows. The actual percentage will fluctuate depending on the increase or decrease that is occuring in the total cow population (Pugh, 1978). In 1979, 18.6% of all cattle slaughtered in Federally inspected packing plants were positively identified as cows (females that possessed a certain degree of maturity; Agriculture Canada, 1979). It is unlikely that a major decline in this percentage will occur in the near future. Furthermore, in the breeding herd, the failure to conceive is highest for yearling heifers so that more heifers than are actually needed as cow replacements must be held back from the market. This can amount to a delay of several months before slaughter, for some heifers which never bear a calf.

Carcass value is dependent on the carcass grades obtained at the time of slaughter. Under the Canadian beef grading system a carcass is classified into one of 16

possible grades; A1, A2, A3, A4, B1, B2, B3, B4, C1, C2, D1, D2, D3, D4, D5 or E. The regulations for doing this are described in a section of the Canada Agricultural Products Standards Act (1978). There are three factors which are considered; carcass maturity, carcass condition and carcass quality.

The first factor considered by the grader is carcass maturity which is particularily important when dealing with cows. Each carcass is classified into one of three maturity divisions (youthful, intermediate and mature) based on a visual assesment of the degree of skeletal ossification that has occured. The cartilaginous regions located at the summits of the spinous processes of the thoracic vertebrae are especially important in making this assesment.

Within each maturity division, carcasses are further classified according to their condition (muscling and fatness). For youthful carcasses, the external fat cover is used to make this classification. These carcasses are knife ribbed between the 11th and 12th ribs so that the thickness of subcutaneous fat ("minimum point of thickness in the fourth quarter from the vertebrae along the longitudinal axis of the *Longissimus dorsi* muscle") can be measured. Table 1 shows the level of fat associated with eight grades in the youthful maturity class. A similar situation exists for carcasses of intermediate maturity, except that there are fewer possible grades. In the intermediate maturity class the excessively fat animals (roughly equivalent to the

Table 1 Carcass Grade as Determined by Fat Level and Carcass Weight Within the Youthful Maturity Class

(Fat Level, Inches)

	CARCASS WEIGHT <500 lbs (<227 kg)	500-700 lbs (227-317 kg)	>700 lbs (>317 kg)
CARCASS GRADE			
A4	>.7	>.8	>.9
A3	.5-.7	.6-.8	.7-.9
A2	.3-.5	.4-.6	.5-.7
A1*a*	.2-.3	.2-.4	.3-.5
B1*b*	.1-.2	.1-.2	.2-.3
C1*b*	<.1*c*	<.1*c*	<.2*c*
C2*b*	<.1*d*	<.1*d*	<.2*d*
D5	0	0	0

a generally considered the optimum level of fat
b carcasses in these grades may have more fat than indicated if dark coloured muscle or yellow fat makes them ineligible for a higher grade
c carcass must have at least a light fat covering over rounds, loins, ribs and chucks
d carcass must have at least a slight fat covering over the ribs and loins

level of fat on an youthful A4 carcass) grade D4. Intermediate carcasses with "at least a light fat covering extending over the rounds, loins, ribs and chucks" are graded C1 while underfinished carcasses are placed in the C2 or D5 grades as indicated in Table 1. Mature carcasses are assigned grades without knife ribbing, on a visual assesment of carcass condition. Excessively fat carcasses are placed in the D4 grade. The other mature carcass grades are D1, D2,

D3 and D5. D1 carcasses are well covered with fat and have "good to excellent" muscling. D2, D3 and D5 carcasses have progressively less fat and poorer muscling.

Carcass quality is the third factor which determines carcass grade. Carcasses can be downgraded for such things as yellow fat, dark coloured lean or pronounced masculinity. The colour of lean is assessed from the exposed cross section of the *Longissimus dorsi* muscle (commonly referred to as the "rib eye"), after knife ribbing. All carcasses from entire males showing "pronounced masculinity" or coarse, dark rib eyes are downgraded to an E grade. Potential A grade carcasses are occasionally moved to grade B due to dark coloured lean or yellow fat. Other examples of downgrading for quality are possible under the grading regulations but seldom occur.

The grade that is eventually placed on the carcass determines how that carcass is to be used (Agriculture Canada, 1976). Those carcasses in the A1 and A2 grades are likely to be retailed through supermarkets. Carcasses in the B grades, C1 grade or D1 grade are likely to be cut up for the hotel, restaurant and institutional trade. Underfinished C and D carcasses, and many D1 and D2 carcasses are boned out and used in a ground or otherwise processed form. According to the Commission of Inquiry into the Marketing of Beef and Veal (1976), most of the increase in the per capita consumption of beef during the sixties and early seventies was youthful, grade A beef. However, the same commission

also identified a growing trend to consume more meals outside the home, possibly 50% by 1985. Ground beef and lower quality, tenderized beef could play a large role in satisfying this demand.

For cows in the breeding herd, body fat is only useful as an energy store. Cows are often allowed to gain weight when feed is cheap and available so that less feed is required later on. Feeding excess amounts of feed is an unnecessary expense and may lower the reproductive productivity of the cow herd (Ludwig *et al.* 1967). Because of this, cows in a well managed beef herd seldom have enough fat for an optimum carcass grade. This is especially true at weaning, after the nutritional demands of pregnancy and lactation have been met, when most of the culling is done. There is an opportunity here to increase the value of the carcass, and therefore the live animal, by a period of high energy feeding before slaughter. The youngest cows have the most to gain in terms of carcass grade. Youthful cows that can potentially yield an A1 carcass grade after grain feeding may only yield a D5 carcass grade if slaughtered in lean condition.

The scientific literature contains a limited amount of information on the feedlot performance of these animals. Using a 116 day feeding period, Howes *et al.* (1972) reported gains of 1.5 kg/ head/ day and a feed/ gain ratio of 8.5 for 40 cows on a 5% roughage ration. On a 15% roughage ration 47 cows in the same experiment gained 1.5 kg/ head/ day with a

feed/ gain ratio of 8.9. At slaughter, these cows were overfat by present standards. Ten cows slaughtered a month before the feeding trial ended averaged .95 inches (2.4 cm) of backfat. A shorter feeding periods would have been more appropriate for the current grading system. Swingle *et al.* (1979), using an 80% concentrate ration, reported a daily gain of 2.28 kg/ head/ day and a feed efficiency of 5.00 for 5 cows fed for 38 days; a daily gain of 2.04 kg/ head/ day and a feed efficiency of 5.16 for 3 cows fed for 63 days; and a daily gain of 1.90 and a feed efficiency of 6.16 for 3 cows fed for 108 days. The differences were not significant. In two more trials, comparing diets of different energy levels (total of 24 cows in 4 treatments), Swingle *et al.* (1979) found daily gains to be well in excess of a kg/ head/ day, and feed efficiencies ranging from 7.65 to 12.04.

One factor that neither of these studies examined was cow age. The "cull cows" removed from a typical breeding herd include cattle of widely differing maturity. In addition to the fully mature cows, there are young heifers which were held for breeding purposes but have failed to produce a calf. These heifers should be about two years of age when culled. There are also young cows which have had at least one calf but are still immature in some respects, such as body size. It is the opinion of some cattle feeders that these young cows, sometimes referred to as "heiferettes" may be a more profitable feedlot animal than the mature cow, both in terms of providing faster and more efficient gains,

and eventually producing a more youthful carcass.

B. DEVELOPMENTAL AND CATCH-UP GROWTH

"Growth" is the result of a variety of processes that occur in the animal body. Positive growth results from an increase in the number of cells (hyperplasia), the size of the cells (hypertrophy) or the amount of non-cellular material associated with each cell (accretion). Growth can also be negative. Most investigations into the growth of farm livestock deal with immature animals. In this situation there are two types of positive growth which may occur: "developmental growth" and "catch-up growth".

Developmental growth is the process by which a young, immature animal transforms itself into a mature adult. The allometric equation proposed by Huxley (1932), $y=mx^b$, where y equals the size of a part and x equals the size of the whole, can be used to describe the growth of various body parts or body tissues, relative to the whole body, quite well (Tulloh, 1963). This implies that during developmental growth the shape and the composition of the animal are dictated by its stage of development, regardless of the rate of growth. Fat is a possible exception to this rule (Elsley *et al.* 1964). The pattern of development for the fat-free body is related to the functional demands placed on it while fat acts primarily as an energy store (Bryden, 1969). It is usually assumed that the rate of developmental growth occurring during *ad libitum* feeding is equivalent to the

genetic maximum for that animal, but as Elsley (1976) pointed out, there are also behavioral and environmental factors which may limit growth.

Animals which have had developmental growth slowed, due to a period of undernutrition, often exhibit an extremely rapid rate of growth when the nutritional restriction is removed. This rapid growth has been the subject of reviews by Wilson and Osbourne (1960) and by Allden (1970). It is probably due to the resumption of a normal rate of developmental growth plus additional catch-up growth.

Catch-up growth occurs because not all tissues are affected by undernutrition to the same degree. During the recovery phase, those parts of the body which suffered the greatest weight loss attempt to catch up so that the body as a whole recovers its proper shape and composition in relation to its stage of development. Since all parts of the body are affected by undernutrition to some degree, compensation is seldom complete. In beef cattle, the results of Winchester and Howe (1955) are typical in this respect. Using six sets of identical twins, they found that restricted-recovered steers took longer to reach 454 kg (1000 lbs.) than continuously fed steers. It is unlikely that restricted cattle can ever be larger than continuously well nourished cattle of a similar age and breeding.

If, in the absence of any growth restriction, body size (or the size of part of the body) is plotted against time a sigmoid curve is produced. This curve is often referred to

as the "curve of growth" (Medawar, 1947). It represents the maximum rate of developmental growth possible at any given stage of maturity. An important feature of this curve is the declining rate of growth after puberty (the point of inflection). Because of this, animals recovering from some form of nutritional deprivation at a late stage of maturity are likely to have a low rate of developmental growth. This, in turn may increase the energy available for catch-up growth.

C. RECOVERY FROM WEIGHT LOSS IN CULL COWS

The demand for energy and protein that arises from pregnancy and lactation results in the beef cow being in unusually lean condition at weaning. In dairy cows, it has been found that the loss of weight during pregnancy and lactation is associated with a shrinkage of muscle fibers as well as a loss of fat (Reid *et al.* 1980). If cows in this condition are sent directly to the packing plant, the results are poor carcass grades and low carcass weights.

An alternative is to feed the cows a high grain finishing ration before slaughter. Although cull cows have seldom been studied in the past, the nature of their weight gains in the feedlot can, in part, be estimated from experiments involving younger cattle.

Gut Fill and Intake

Often changes in diet lead to rapid weight changes due to changing gut fill (Lyon *et al.* 1970, Tayler *et al.* 1957).

This is especially true when cattle are taken from a low level of intake and allowed unrestricted access to feed. During the period spent working up to *ad libitum* intake (commonly refered to as "full feed") from a restricted level of intake, gut fill, and therefore liveweight can be expected to steadily increase. Voluntary intake is often highest for animals that have previously undergone a nutritional restriction. This has been demonstrated in sheep (Graham and Searle, 1975) and cattle (Hironaka and Kozub, 1973). Saunbidet and Verde (1976) have found that in this situation age was a better predictor of intake than weight.

The mechanism by which cattle might regulate intake in the recovery period is uncertain. According to Forbes (1978) there is no good evidence of a lipostatic control mechanism for feed intake in cattle although there is evidence that increasing internal fat deposits may serve a similar purpose by restricting the physical capacity of the gut. The importance of this will be less on a concentrate diet where gut capacity is less important in regulating voluntary intake (Baille and Forbes, 1974; Bines and Davey, 1970).

Noncarcass Gains

The offals, or those parts of the empty body not included in the carcass, also play a role in the compensatory growth response. Not all the offals are equally affected by weight loss and recovery. There is evidence in cattle (Murray *et al.* 1977) and sheep (Winter *et al.* 1976) that certain offals such as the liver, heart, alimentary

tract fat and alimentary tract tissue (except large intestine) lose weight relatively faster than the whole body during restriction and regain weight relatively faster than the whole body during recovery. In this way they insulate the remaining parts of the body against short term fluctuations in the level of nutrition. This means that rapid liveweight gains early in the recovery period may not be reflected in rapid carcass weight gains.

Bone Growth

Cattle on low planes of nutrition display reduced rates of bone growth although bone is not affected to the same extent as some other tissues (Hammond, 1947). Stuedemann *et al.* (1968) found carcass length to be reduced in underfed beef calves and Allden (1968) obtained the same results measuring live animal length in sheep. While the time required to reach mature size may be increased by a period of undernutrition (Hogan, 1929), it is thought that the ultimate mature size will be similar regardless (Allden, 1968). There is no good evidence in sheep or in cattle that linear bone growth can ever excede a normal rate of developmental growth to compensate for a period of undernutrition. Rapid changes in bone weight during weight loss and recovery may reflect changes in bone composition rather than changes in the physical dimensions of the bones. It is generally believed that total bone fat and bone ash decrease during malnutrition while bone water increases (Himes, 1978). However, in times of energy shortage, bone

fat will not be drawn upon until other fat depots are quite low (Russel, 1968). In young sheep, the results of Drew and Reid (1975*b*) suggest that this fat may continue to be mobilized early in the recovery period. Bone is a dynamic tissue and the various components (protein, fat, water and minerals) can undergo some complex changes during undernutrition and recovery. Unlike muscle or adipose tissue, changes in bone weight that occur in response to a change in the plane of nutrition do not always reflect changes in the total energy content of the bone (Drew and Reid, 1975*b*).

Muscle and Fat

Since undernourished animals have a lower proportion of fat and recovered animals tend to have normal proportions, it has been concluded that growth during the recovery period contains an abnormally high proportion of fat (Wilson and Osbourne, 1960). In spite of this there is good evidence in cattle and sheep that the initial growth during the recovery period contains a high proportion of protein plus water (Butterfield, 1966; Fox *et al.* 1972; Drew and Reid, 1975a). Wooten *et al.* (1979), working with cull cows, found that the proportion of fat in the carcass gain increased as the time on feed increased. Reid and Robb (1971) reviewed three experiments dealing with weight gains and losses in non-pregnant cows. The estimates of per cent fat in the empty body weight gain (or loss) ranged from 55% to 90%. They also suggested that the differences could be due to the

level of fat present at the start of the experiment.

A primary function of fat is as an energy store (Young, 1976). Because of this, its growth is partly regulated by the nutrient requirements of the other tissues. Young cows, with the potential for developmental growth as well as catch-up growth should have a higher potential for muscle growth than mature cows. Therefore, the younger cows may fatten less rapidly. Callow (1950) reached this conclusion from carcass dissection data that included both mature and immature cattle. He estimated that 58% of the carcass weight gain for the mature cows was fat while only 39% of the carcass weight gain in the young steers and 39.5% of the carcass weight gain in the heifers (2 or 3 years of age) was fat. However, it has also been found that other factors such as diet, rate of gain and biological type can substantially alter the composition of the carcass weight gains in young cattle (Byers, 1980).

It is normally thought that undernutrition causes no permanent damage to the muscle tissue, and that upon refeeding there will be a full recovery (Yeates, 1964).

Possible Effects of Age on Growth After Maturity

There is a possibility that after maturity the size of some tissues decreases or the ability to restore some tissues may be partly lost. Lean body mass is known to decline in very aged animals. Shock (1962) reported that senile rats often show evidence of a lowered muscle weight and a decrease in the number of muscle fibers, and that much

of the space formerly occupied by these lost muscle fibers becomes filled with connective tissue. Rowe (1969) found that by 750 days of age, mouse muscles displayed a loss of fibers, and in males a lower muscle weight. He pointed out that the lack of a muscle weight loss in females may have been related to an increase in body weight. These mice were approaching the end of their expected lifespan (about two years) as listed by Spector (1956).

If not prematurely terminated by man, the average lifespan for cattle would be in excess of 20 years (Spector, 1956). In a commercial beef herd, few cows ever reach an age where they can be considered senile. However, according to the measurements made on humans and reported by Forbes and Reina (1970) the decline in lean body mass may begin much earlier.

Age may also reduce the ability of some tissues to respond to damage or tissue loss. Goss (1964) uses the example of partial hepatectomy in rats where it is commonly found that the length of time needed to restore the tissue increases with age.

D. COW AGE AND MEAT QUALITY

Age and Meat Tenderness

Lawrie (1974) is of the opinion that of all the characteristics responsible for determining the eating quality of beef, the consumer considers texture and tenderness the most important. Since increasing animal age

at slaughter has long been thought to reduce tenderness and make beef less desirable, most beef carcass classification systems include some estimate of animal maturity.

Although very subjective, scoring of tenderness by trained taste panels has been one of the best methods for evaluating this characteristic. In this way Reagan *et al.* (1976) found that cows between 3635 and 9828 days of age showed a significant decrease in tenderness with age while younger groups did not. Hunsley *et al.* (1971) showed no differences in tenderness among cattle slaughtered at 6, 9, 12, 15, or 18 months of age. Prost *et al.* (1975b) reported no differences between cattle 6 to 8 weeks of age and those 5 to 8 months of age. There was, however, a definite decline in tenderness before the cattle became "adults" (2 to 5 years of age). Goll *et al.* (1965) found that beef from cattle 8 to 10 years of age were less tender than that from cattle under 24 months of age.

The Warner-Bratzler shear has been used as an objective method of estimating tenderness. It has been pointed out (Bouton *et al.* 1975) that the peak shear force recorded by the Warner-Bratzler shear may be determined more by the characteristics of the muscle fibers than the connective tissue. Using this method, tenderness was found to decrease from 6 to 9 months of age and then increase to 18 months of age by Hunsley *et al.* (1971). Prost *et al.* (1975b) found that beef from cattle 5 to 8 months of age was less tender than that from cattle 6 to 8 weeks or 2 to 5 years of age.

In this experiment there was no decline in tenderness detected between 5 months and 2 years of age. Walter *et al.* (1965) confirmed the results that Goll *et al.* obtained using sensory evaluation. Also using the Warner-Bratzler shear, Goll *et al.* (1963) showed beef from 10 year old cows to be less tender than beef from 5 year old cows while Dryden *et al.* (1979) detected a small drop in tenderness from 3 to 10 years of age.

It appears from these results that changes in tenderness probably do occur during the first few years of life, although these changes are probably not linear. In older cattle there seems to be a gradual decline in tenderness that continues throughout life.

The reasons for the general decline of tenderness with age have also been investigated. Prost *et al.* (1975a) estimated the connective tissue content of beef by a hydroxyproline method and a histometric method. They found that at 5 to 8 months of age cattle had more connective tissue relative to total protein than at younger or older ages. Therefore, changes in the connective tissue content of the muscle could not explain the decline in tenderness that occurred with age. Other authors have suggested that the structure of the connective tissue may change with age. Schmidt and Parrish (1971) found that connective tissue fibers from mature cattle (U.S.D.A. maturity D, about 54 to 60 months of age) were larger and showed a greater degree of aggregation than those from less mature cattle. The

connective tissue from the mature group was also more resistant to heat. Marsh (1977) has pointed out that older cattle have a greater degree of crosslinking within the connective tissue. This may make the collagen more resistant to breakdown during cooking. This would explain why differences in shear values between veal and U.S.D.A. maturity A carcasses are reduced after heating to temperatures greater than 60°C (Schmidt *et al.* 1968). Because of the changes in collagen crosslinking with age, soluble collagen has been proposed as a measure of tenderness. Cross *et al.* (1973) found that per cent soluble collagen fell between 305 and 5096 days of age while chemical measurements of total collagen or elastin did not. The relationship between per cent soluble collagen and the sensory evaluation of tenderness was still poor.

Part of the effect of age on tenderness may not be related to changes that occur in the connective tissue but to changes that occur to the muscle fibers. Cooper *et al.* (1968) found that mature cattle had larger fiber diameters, larger muscle bundle cross sectional areas and shorter sarcomeres than younger cattle. This would usually indicate a high degree of muscle contraction and Locker (1960) has found that muscle contraction decreases tenderness. However, Covington *et al.* (1970), working with three U.S.D.A. maturity groups, found that increasing maturity led to larger fiber diameters but not to changes in sarcomere lengths. In young, rapidly growing cattle both sarcomere

length and fiber diameter are expected to increase with age since it is known that growth in muscle length is the result of both more and longer sarcomeres (less overlap between protein filaments) and growth in width is due to thicker fibers (Goldspink, 1970).

Physiological Maturity and Meat Quality

According to Allen *et al.* (1974) "Physiological maturity is a term used to refer to the relative stage of development of body processes, functions or composition". It is important not to confuse growth rate or mature size with the rate of maturation. Fitzhugh and Taylor (1971) pointed out that the growth rate and rate of maturation are somewhat independent. Smith *et al.* (1976) found that heterosis affects maturation rate more than mature size. A number of different authors have obtained significant differences when comparing the rates at which specific characters mature among breeds. Gregory *et al.* (1978) found that there were breed differences in the age of puberty (first estrus) in heifers. It was suggested by Guenther (1974) that Angus cattle matured faster in terms of muscle fiber diameter than Charolais. Andrews and Wedderburn (1977) found differences in the time of eruption of the first pair of permanent incisor teeth.

Because all animals do not mature at the same rate, physiological age may be a better indicator of meat quality than chronological age. Regardless, an estimate of physiological age must be used for a commercial beef grading

system since the exact chronological age cannot be reliably determined. As described earlier, the Canadian beef grading system classifies beef carcasses into one of three maturity divisions based on a visual estimate of the degree of ossification that has occurred in the skeleton. The U.S.D.A. system, which also take the colour of lean into consideration uses five maturity divisions. The ability of these systems to predict meat tenderness has been investigated. Thomassen *et al.* (1979) concluded that under the Canadian system, Maturity I (youthful) carcasses were more tender than Maturity II (intermediate) carcasses. Berry *et al.* (1974), after investigating the U.S.D.A. system , decided that among the lower maturity divisions differences in tenderness were small and fewer divisions would be adequate. One critisism of using skeletal ossification for estimating physiological age is the subjective way in which the classification is made. Other countries, such as the United Kingdom and New Zealand rely on the eruption of permanent incisors as a more objective method for estimating physiological age.

E. EXPERIMENTAL INTENTIONS

As discussed in this introduction, the decline in beef tenderness with age makes it important to discriminate against the older carcasses in the grading system. Carcass value, however, is dependent on carcass weight and composition as well as meat quality. Age, until the time

full maturity is reached, affects the type of growth (positive or negitive) which can occur and the priorities of the various tissues for nutrients. In this way, cow age may determine slaughter value at the time of culling or after feedlot finishing. It is the latter case, or the response to grain feeding, that is of special interest since all cull cows are destined for slaughter eventually. When contemplating the merits of grain feeding for these cows, the benefits (improvement in carcass value) must be weighed against the costs. The following experiments were conducted to examine the effect of age and grain feeding on the carcasses of cull cows. Special attention was given to carcass composition and carcass grade.

II. EXPERIMENT #1: KINSELLA RANCH

A. BACKGROUND

Cows from the University of Alberta herd provided suitable subjects to begin the experimental investigation. The cows in this herd have always been treated very much as they would be in a commercial herd. Therefore, they can be considered representitive of cows which might be culled from any number of herds in Western Canada.

The best way to measure the relative amounts of the various carcass tissues is to take one side and physically separate it into muscle, bone and fat. This procedure is very time consuming and impractical for experiments that must be completed in a reasonable length of time. For preliminary studies, some conclusions on the merits of a particular group of carcasses can be drawn using some reasonably simple measurements. Such techniques have been used here to determine the effects of age, breed, and high energy feeding on the carcasses of cull beef cows. The following traits were examined:

1. Hot Carcass Weight

   Fredeen *et al.* (1971) found the correlation between carcass weight and weight of lean in the carcass to be .84 or greater for bulls, steers and heifers. In the current experiment, among cows of similar fatness, it was probably the best indicator of the amount of salable

meat present.

2. Carcass Length

Carcass length can be used as an estimate of skeletal size. This is particularily useful because of the special relationship between skeletal size and developmental growth. When nutrients are limited, bone growth takes priority over muscle and fat growth (Hammond, 1947). If adequate nutrients are then supplied it seems probable that the rest of the tissues would attempt to catch-up and restore the proper composition to the animal body (see Introduction). Carcass length can therefore be used to determine how much developmental growth has already occurred and how much is yet to occur before full maturity is reached.

3. Rib Eye Areas

Brackelsburg *et al.* (1968) have shown that the area of the rib eye is correlated to the weight of separable muscle in a carcass. The relationship is not very precise but could be meaningful when comparing groups of cattle.

4. Fat Thickness Over the Rib Eye

Fat thickness over the rib eye has been shown to be a good predictor of the carcass yield of trimmed prime cuts (Martin *et al.* 1970), per cent carcass fat (Charles, 1977; Crouse and Dikeman, 1974; Powell and Huffman, 1973) and weight of separable carcass fat (Brackelsberg *et al.* 1968). The use of fat thickness as

a predictor of total carcass fat in the current experiment depended on the relationship between subcutaneous fat and total carcass fat. Kempster *et al.* (1976) used the allometric equation to study this relationship among different breeds and they concluded that there were some small differences. There has also been evidence to show that during recovery from weight loss, the subcutaneous fat depot is the last to be replenished (Berg and Butterfield, 1976). Since the present experiment involved the recovery from undernutrition, any prediction of total carcass fat based on the subcutaneous fat depot may have tended to underestimate increases in total carcass fat during the recovery period.

5. Caul Fat

In this experiment, "caul fat" referred to the abdominal fat attached to the outside of the rumen. Like other fat deposits, abdominal fat is known to increase relatively faster than the empty body during developmental growth and decrease relatively faster than the empty body during weight loss (Seebeck, 1967). Using this portion of the abdominal fat deposit (caul fat) as a predictor of total carcass fat had some advantages because it was easily obtained on the slaughter floor and did not require the destruction or mutilation of the carcass.

6. Presence or Absence of Liver Abscesses

A high incidence of liver abscesses, which results in

the livers being condemned as unfit for human consumption, has been associated with high concentrate diets (Brown *et al.* 1975) and it was suggested that those cattle with severe abscesses have reduced rates of gain. Foster and Woods (1970) reported that adding 5% roughage to an all concentrate diet reduced the number of abscessed livers. Since the liver is an edible part of the carcass, it is of interest from a commercial point of view to know how the high grain ration will affect losses of this type in grain fed cows.

7. Carcass Weight Adjusted to a Common Carcass Length

If developmental growth is still occurring in immature cows, then an analysis of variance should show heavier carcass weights with increasing age. Adjusting the carcass weights to a common carcass length, as a measure of skeletal size, can be used to test the importance of factors other than skeletal size in determining carcass weight among age and breed groups. The "fleshing index", developed by Yeates (1952) uses carcass length and carcass weight in a similar fashion. Those animals with superior "fleshing" (muscle: bone ratio) should have heavy carcasses in relation to their length. The work of Abraham *et al.* (1968) can be used to support this interpretation of adjusted carcass weight data. They calculated the partial regression coefficient between carcass weight and the weight of boneless steaks and roasts, holding carcass length and fat thickness over

the rib eye constant, to be .90. This indicated that carcass weight could explain a substantial portion of the variation in boneless, trimmed steaks and roasts not explained by length or fat thickness. In contrast to this, the partial regression coefficient between length and boneless steak and roast meat, with carcass weight and fat thickness held constant, was .04. This meant that all the variation in boneless, trimmed steaks and roasts explained by length was also explained by the other two variables.

8. Rib Eye Areas Adjusted to a Common Carcass Length

The use of carcass length to improve the relationship between rib eye areas and the weight of separable carcass muscle has been suggested in the past. With pigs, McMeekan (1941) tried unsuccessfully to improve the relationship between separable lean and rib eye length and depth measurements. With cattle, Cole *et al.* (1962) demonstrated that by using rib eye areas multiplied by carcass length, or by including both variables in a multiple regression equation, a better prediction of carcass lean than could be made using rib eye areas alone was the result. An alternative would have been to use carcass weight as a covariate. However, since carcass lean (the variable that rib eye area was meant to predict) was likely to account for over half of the total carcass weight, there remained the possibility that other differences in muscling which were not due to

the stage of developmental growth or the level of fatness might also be adjusted out. It was these remaining differences for which this type of analysis was to test. Cole *et al.* (1960), by holding weight constant, were able to reduce the partial regression coefficient between loin eye area and carcass lean to .04. The simple regression coefficient was .43. Thus, even though the covariate weight is likely to be highly significant, possibly even more so than carcass length, the interpretation of the final results would have been be less clear.

B. METHODS AND MATERIALS

Eighty-seven cows were used in this experiment which ran from February to June of 1979. All of the cows were from the University of Alberta herd. These cows were culled because they had failed to conceive during the breeding season. Each animal was classified into one of three breed groups; Hereford (HE), Beef Composite (BC) and Dairy Composite (DC). The HE cows were purebred while the BC and DC cows were crossbred. The breed composition of each cow was known. The BC group were mainly a mixture of Angus, Charolais and Galloway, while cows in the DC group contained a large proportion of Holstein, Brown Swiss or Simmental. These breed groups differed in mature size and propensity to fatten. The HE group were small and early fattening, the DC group were large and late fattening while the BC group were

intermediate.

The cows were also classified into one of three age groups; 2 or 3 years of age (Y), 4 or 5 years of age (I) and 6 years of age or greater (M). This classification system was chosen based on previous observations that it roughly corresponded to the three maturity divisions of the Canadian beef grading system. Except for the two year olds, all cows had raised a calf during the previous summer. For over a month, between the time they were culled from the herd and the start of the experiment, all cows were maintained on an all roughage diet.

One third of the cows, selected at random within each age x breed group, were slaughtered at the start of the experiment. The remaining 59 head were separated into pens (2 pens per breed group). The age group composition of the pens was kept as close as possible, otherwise, this separation was made at random. After eight weeks, one half of the animals in each pen x age group was randomly selected and slaughtered. The remainder were killed after a further eight weeks. The number of cows in each age x breed x slaughter cell are shown in Table 2. Only one of these cells was empty. There were no HE cows of I age in the final slaughter group.

Previous experience at the Kinsella ranch had indicated that cows were particularily susceptible to digestive problems upon introduction to a grain ration. For this reason, about half of the first eight week period was spent

Table 2 Slaughter Group, Age and Breed Distribution for 87 Cull Cows

(number of cows)

INITIAL SLAUGHTER GROUP	BREED		
	HE	BC	DC
AGE			
Y	3	8	6
I	1	3	2
M	1	2	2
8 WEEK SLAUGHTER GROUP	**BREED**		
	HE	BC	DC
AGE			
Y	2	8	8
I	1	4	3
M	2	1	1
16 WEEK SLAUGHTER GROUP	**BREED**		
	HE	BC	DC
AGE			
Y	3	8	7
I	0	3	3
M	2	2	1

working towards an *ad libitum* level of intake for the diet shown in Table 3. Prior to this, the cows had been fed only long, alfalfa-grass hay. On day one, each cow received 6.3 kg/head of the grain mixture plus an additional 3.6 kg/ head of the alfalfa-grass hay. The amount of hay fed was reduced by .45 kg/ head/ day for the next five days and then left constant for four more days before eliminating it altogether. The grain mixture was increased in steps. Seven

Table 3 Kinsella Cow Diet

INGREDIENT	AIR DRY COMPOSITION (kg/tonne)
Rolled Barley	620
Rolled Oats	200
Pelleted Alfalfa	100
Rapeseed Meal	58
Calcium Carbonate	10
Dicalcium Phosphate	5.2
Vit mash (A,D,E; 4 pts. grain:1 pts. supplement)	2.6
Trace Mineral Salt	2.6
Molasses	1.6

consecutive increases of .45 kg/ head/ day were followed by a five day period when feed intake was kept constant. The same procedure, where feed intake was increased for a few days, then held constant for a few days was repeated. When intake reached 11 kg/ head/ day the increases were limited to .23 kg/ head/ day. During this time twice a day feeding was used. After four weeks, when *ad libitum* intake was finally reached, three of the pens (one from each breed group) were fed from self feeders. The remaining pens continued to be fed once a day but to a slight excess so that intake would not be limited. Throughout the experiment the three self fed groups were held in outdoor pens. The remaining three pens were partly covered by an open sided shed which provided some shelter for the manger area.

The same slaughter procedure was followed each time a group was marketed. All cows on the experiment were removed from water and feed on Monday night. The next day, each cow was weighed and those destined to be slaughtered were sorted out. Early Wednesday morning these cows were shipped 150 kilometers and slaughtered at a commercial packing plant.

Each cow was weighed immediately upon arrival at the packing plant. Following this, they were all killed as soon as possible. The time of slaughter was never more than a few hours after their arrival. On the killing floor identification tags were placed on each carcass as the hide was removed. As the internal organs were removed, the caul fat was separated from the rumen and weighed. The presence or absence of liver abscesses was recorded at the same time. The carcasses were then weighed, washed, shrouded and sent to the cooler to be chilled overnight.

The next morning, Agriculture Canada graders assigned a grade to each carcass. The graders also estimated rib eye (*Longissimus dorsi*) areas with the aid of a grid marked off in 1.6 cm^2 (.25 $in.^2$) units. In addition, they measured and recorded the thickness of fat over the rib eye. This was done at the site where the grading measurement is taken and as the average of three measurements (measuring perpendicular to sites one quarter, one half and three quarters the length of the rib eye). Finally, the length of each carcass from the anterior edge of the pubic symphysis to the anterior edge of the first thoracic vertebra was

measured by Department of Animal Science personel.

Statistical Analysis

The carcass data were analysed by a least squares analysis of variance procedure (Harvey, 1960). This method of analysis was made necessary by the unequal cell size. The model used is shown in Table 4. The missing cell resulted in only 7 degrees of freedom for the age x slaughter group x breed term. All F tests were done with the bottom line error as shown in the table. For the purposes of this analysis, pens in each breed x slaughter group cell were considered to be completely independent of one another. They were actually the same pens throughout the experiment for each breed but the number of animals per pen decreased by half between the first and second feeding periods. The control group which was never fed the grain ration, were all assigned to the same "pen" within a breed group.

A two way analysis of variance was used to test for the effects of breed and length of time on feed, on the average daily gain and average feed conversion within the various pens.

Two runs of analysis of covariance were also performed on these data. The first run used hot carcass weight as the dependent variable and carcass length as the covariate. The second run used rib eye areas as the dependent variable and carcass length as the covariate. The differences in rib eye area and hot carcass weight which remained after these adjustments were those which were unexplained by differences

Table 4 Statisical Models for Analysis of Variance

SLAUGHTER DATA		FEEDLOT DATA	
Source	d.f.	Source	d.f.
Slaughter groups (S)	2	Feeding period (F)	1
Breed group (B)	2	Breed group (B)	2
S x B	4	F x B	2
Pens (P)/ S x B	6	Error (Pens/ F x B)	6
Age groups (A)	2	Total	11
A x S	4		
A x B	4		
A x S x B	7		
Error (Animals/ P/ S x B; plus A x P/ S x B)	55		
Total	86		

in skeletal size.

Within the present experiment there was no reason to include fat thickness as a covariate (see Background) since most of the variation in fat thickness was explained by length of time on feed (one of the main effects in the statistical model).

In both weight/ length and rib eye area/ length analysis, the slope of the regression line for the covariate provided an estimate of the changes that occur in the dependent variable during developmental growth.

C. RESULTS AND DISCUSSION

The rate of gain and the feed efficiency for the 3 breed groups and the 2 time periods are shown in Table 5. Breed group had no effect on average daily gain or feed efficiency. Daily gain declined with time, from 1.80 Kg/day in the first 8 weeks to 1.13 Kg/day in the last 8 weeks ($p<0.01$). Feed efficiency also declined from 6.90 to 12.81 ($p<0.01$). In cattle, prolonged undernutrition leads to lower maintenance costs (Ledger and Sayers, 1977). It is doubtful, however, that this would persist long into the recovery period. There is no way of determining how much of the weight gain in period 1 was due to increasing gut fill since intake was limited prior to the start of the experiment and approximately four weeks of period 1 had passed before the cows were allowed unrestricted access to the feed. Presumably, gut fill would increase as intake increased. The differences in feed efficiency could also reflect a high proportion of protein in the early gains. Growth consisting of a high proportion of lean is more efficient, on a weight basis, than growth that contains a high proportion of fat, since protein is associated in the animal body with more than 3 times its own weight of water (Reid *et al.* 1968)

Table 6 shows the live weight at slaughter (plant weight) and the carcass characteristics of the 87 cull cows. There were no significant differences among breeds for live plant weight, hot carcass weight or carcass length ($p>0.05$). These three characteristics are all measures of body size.

Table 5 Feedlot Performance of 87 Cull Cows Fed for Eight or Sixteen Weeks

	NUMBER OF PENS	DAILY GAIN (KG)	FEED PER GAIN
BREED GROUP			
Hereford	2x2 *a*	1.48	9.48
Beef composite	2x2	1.45	9.88
Dairy composite	2x2	1.46	10.20
s.e.		.10	1.26
TIME PERIOD			
#1 (weeks 1-8)	6	1.80	6.90
#2 (weeks 9-16)	6	1.13	12.81
s.e.		.08*	1.03*

* $p<0.05$
a two pens by two time periods

Goonewardene (1978) observed differences in live weight among these same breed groups in the University of Alberta herd (referred to by him as Herefords, Beef Hybrids and crosses with large dairy breeds).

There was a significant difference ($p<0.05$) among breeds in rib eye area. HE cows had rib eyes that were 10 cm^2 smaller than the BC cows. This was consistant across all age and slaughter groups.

For average fat thickness and weight of caul fat there were no differences ($P>0.05$). Thus, in terms of these carcass measurements, the different breed groups used here were very similar. They were also similar in the proportion

Table 6 Live Weight and Carcass Data for 87 Cull Cows

Least Squares Means±Standard Errors

	n	(1) Live Weight(kg)	(2) Carcass Weight(kg)	(3) Length (cm)	(4) Rib Eye Area(cm^2)	(5) Average Fat(mm)	(6)*d* Caul Fat(kg)	(7)*e* %Liver Abscesses
BREED GROUP		n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.
HE	15	488±17.0	266±10.1	128±1.4	62.7±3.22*a*	10.0±1.29	4.6±0.41	27±12.3
BC	39	494±11.0	273±6.5	130±0.9	72.7±2.08*b*	8.6±0.83	3.9±0.26	16±7.9
DC	33	491±12.0	269±7.1	132±1.0	70.5±2.27*ab*	8.0±0.90	4.1±0.28	19±8.6
AGE GROUP		**	**	**	n.s.	n.s.	**	n.s.
Y	53	426±8.3*a*	236±4.9*a*	121±0.7*a*	65.3±1.56	8.0±0.63	3.3±0.20*a*	24±6.0
I	20	497±16.2*b*	274±9.6*b*	132±1.4*b*	71.3±3.07	8.6±1.23	4.8±0.39*b*	29±11.7
M	14	550±15.0*c*	298±8.9*b*	137±1.3*c*	69.4±2.84	10.1±1.14	4.5±0.36*b*	9±10.8
SLAUGHTER GROUP		**	**	**	n.s.	**	**	n.s.
Control	28	411±12.2*a*	219±7.2*a*	127±1.0*a*	64.3±2.30	2.8±0.92*a*	1.4±0.29*a*	10±9.8
8 Weeks	30	484±13.4*b*	260±7.9*b*	130±1.1*b*	69.8±2.52	9.2±1.01*b*	3.8±0.32*b*	28±9.6
16 Weeks	29	577±13.6*c*	329±8.1*c*	133±1.1*b*	71.9±2.56	14.6±1.03*c*	7.4±0.33*c*	24±8.8

*,** F test; $p<0.05$, $p<0.01$
a,b,c Means within a group are significantly different $p<0.05$.
d Slaughter group X Age group interaction is significant $p<0.05$
e Slaughter group X Breed group interaction is significant $p<0.05$

of cows showing liver abscesses ($P>0.05$).

There were large increases in live weight as cow age increased ($p<0.01$). The results (Table 6) show that the Y group was still 124 kg below mature weight at slaughter (about 77%). The I group was 53 kg below mature weight at slaughter (about 90%). There was also an increase in hot carcass weight with age ($p<0.01$), but this time only the difference between the Y and I groups was significant. Among age groups there was a significant increase in length as the cows matured ($p<0.01$). An examination of these data showed that the Y group was 16 cm shorter than the mature group (88% of mature size), while the I group was 5 cm (not significantly different) shorter than the mature group. It is possible that the rate of developmental growth increased due to the high grain diet. Thus, the potential contribution of developmental growth to the feedlot weight gains of the younger cows may be higher than the relationships between these traits (live weight, carcass weight and carcass length) and age group would indicate.

In spite of the fact that body size (weight and length) increased with age, rib eye areas did not ($p>0.05$). There was a tendency for average fat thickness and weight of caul fat to be less for the Y group. However, only for caul fat was there a significant difference in this respect ($p<0.01$). Y cows also had a 15% higher incidence of liver abscesses, compared to the M group but this difference was not significant ($p>0.05$). The standard errors for this analysis

were very large and the size of the various groups were such that one cow could sometimes make a difference of several per cent. There was a significant slaughter group by breed interaction for liver abscesses ($p<0.05$).

Live weight was 73 kg greater in the second (8 week) slaughter group and 163 kg greater than the control in the third (16 week) slaughter group ($p<0.01$). The length of time on feed also significantly ($p<0.01$) affected hot carcass weight. The second and third slaughter groups were 41 kg and 110 kg greater than the control, respectively. Carcass length also increased with the length of time on feed ($p<0.05$). Obviously these differences could not be explained solely on the basis of age differences among slaughter groups. A growth rate of about 19 cm per year would be required to explain the 6 cm difference over 16 weeks. An examination of the slaughter group x age means revealed that most of the increase occurred in the Y group which went from 116 cm in the control group to 121 cm at 8 weeks and 126 cm at 16 weeks. The I group went from 128 cm in the control group to 131 cm at 8 weeks and 136 cm at 16 weeks, while the mature group averaged 137, 138, and 137 cm for the three slaughter groups. Although bone is not generally thought to exhibit a compensatory growth response, the present results suggest compensation. It must be remembered, however, that the slaughter group x age interaction was not significant ($p>0.05$) and more variation can be expected in the younger groups since these groups contain cows which may differ

slightly in maturity while all the cows in the M group were fully mature. Therefore the magnitude of the differences between slaughter groups should be interpreted with caution. There were no significant differences in rib eye areas among slaughter groups ($p>0.05$). This is in contrast of the results of Price and Berg (1981), who found that rib eye area increased during grain feeding. In the feedlot, these cows should have been laying down muscle tissue as well as fat in the carcasses. There were definite increases in the weight of caul fat and average fat thickness as the length of time on feed increased ($p<0.01$). The slaughter group by age interaction was significant ($p<0.05$) for weight of caul fat, apparently due to slower increases in caul fat of the Y group during feeding ($p<0.01$). Eight weeks feeding was sufficient to produce enough fat for an optimum grade in most cows, however, there were still 11 cows which could have benefited (less than 5 mm of fat or less than required for an optimum grade) from a few weeks further feeding. After 16 weeks some cows were becoming overfat (up to 0.7 in. of fat at the point where the grading measurements were taken), although there were still no A4 or D4 grades. Any differences in the rate of fattening due to age were not large enough to produce noticable differences in this respect (age x slaughter interaction for fat thickness over the rib eye was not significant, $p>0.05$). Grain feeding did not significantly increase the incidence of abscessed livers ($p>0.05$).

The use of linear regression techniques such as occur in analysis of covarience, was acceptable for these data because all of the cattle fell within a limited range of body size. In this case, the relationship between length and weight appeared to be linear. Most length-weight relationships in the growing animal can be best described by the function $W=nL^k$, where W=weight, L=length, and n and k are constants. Usually k has a value near 3. Brody *et al.* (1929), while studying the relationship between live animal length (shoulder to hips) and live weight in young heifers found this to be true. A similar situation existed between carcass length and rib eye area.

The results from the analysis of covariance for hot carcass weight and rib eye areas are shown in Table 7. As in the analysis of variance, there were no differences ($p>0.05$) in hot carcass weights among breed groups. Adjusting rib eye areas for carcass length meant that the HE breed group still had the smallest rib eyes but the differences were not significant ($p>0.05$). The adjustment to a common carcass length removed the differences in hot carcass weight among age groups ($P>0.05$). The adjusted rib eye areas decreased with age, being smaller in the M group ($p<0.05$). This suggested that the mature cows had lower muscle: bone ratios than the younger cows. There is an opinion among some people in the packing industry that cows have small rib eyes. From these results, this appears to be true, at least when carcass length is taken into account. There were increases

Table 7 Hot Carcass Weight and Rib Eye Areas for 87 Cull Cows, Adjusted To a Constant Carcass Length

Adjusted Means±Standard Errors *d*

	n	Hot Carcass Weight (kg)	Rib Eye Area (cm^2)
BREED GROUP		NS	NS
HE	15	258±8.0	60.8±2.79
BC	39	257±5.8	68.4±2.03
DC	33	244±6.9	64.0±2.43
AGE GROUP		NS	*
Y	53	259±5.5	71.5±1.92*a*
I	20	250±8.5	65.1±2.98*a*
M	14	249±10.6	56.7±3.73*b*
SLAUGHTER GROUP		**	NS
Control	28	217±5.6*a*	63.8±1.98
8 Weeks	30	243±6.8*b*	65.3±2.39
16 Weeks	29	299±8.0*c*	64.2±2.79

NS F test, not significant, $p>0.05$
*,** F test; $p<0.05$, $p<0.01$
a,b,c means within a group followed by the same letter are not significantly different ($p<0.05$)
d covariate mean = 126 cm

in the adjusted carcass weights among slaughter groups ($p<0.01$), representing the catch-up growth that occurred during the feeding period. Although it was expected that rib eye areas should increase during the feeding period, the adjusted values showed that the changes that occurred were simply in proportion to the increases in carcass length.

Among slaughter groups the adjusted means ranged from 63.8 to 65.3 cm^2. Thus they appear to reflect a normal pattern of developmental growth.

For both hot carcass weight and rib eye area the covariate (length) accounted for a significant ($p<0.01$) portion of the total variation. The slope of the regression line for the covariate, presumably the best estimate of developmental growth over this age range indicated that for each 1.0 cm of additional carcass length, carcass weight increased by 4.5±.75 kg (±s.e.) and rib eye areas increased by 1.19±.26 cm^2.

In this experiment, the improvement in carcass grade, during grain feeding was due to an increase in the level of subcutaneous fat present. None of the cows in this experiment were down graded due to meat colour or fat colour.

This study showed that as cows age, changes occur in certain carcass characteristics which may reflect changing carcass composition. It is suggested that older cows have less muscle per unit of bone and the carcass gain of these cattle contains a lower proportion of muscle and a higher proportion of fat. In the U of A herd, the principle reason for a cow failing to stay in the herd is a failure to produce a calf every year. Under this system the majority of the cows culled are from the younger age groups. The potential to produce an A1 carcass and their superior muscling gives these young cows a big advantage over the

more mature cows as feedlot animals.

III. EXPERIMENT #2: ELLERSLIE

A. BACKGROUND

The practical merits of grain feeding depend on the costs, as well as the benefits. In the previous experiment, a feed consumption comparison was made among breed groups, not among age groups. Another experiment was needed to supply this information.

The condition of a cow at culling can vary, depending on the previous nutritional history and the time of the year when the culling is done. The condition of the cow at slaughter can also vary depending on the demands of a particular market, slaughter cow prices and expectations of future slaughter cow prices. Therefore, the beginning and end points on the feeding period depend very much on the particular set of circumstances. The extent to which body fat can influence feedlot performance is another question which needs to be examined. The following experiment examined the effect of age and body fat on the feedlot performance of cull cows.

In addition, the investigation begun in experiment 1, into the effect of cow age on the carcass weight gains of cull cows was continued. This time, it was decided that a better method of estimating carcass composition was required over the simple carcass measurements taken at the packing plant. Since total dissection was impractical, the two

alternatives considered were carcass density and a sample joint dissection.

Carcass density, as reveiwed by Jones *et al.* (1978*a*) is particularily effective in predicting the amount of fat (and therefore the amount of fat free tissue) in a carcass. The use of a carcass density measurement to predict carcass composition in terms of muscle, bone and fat assumes that the composition of the fat free body changes only in response to changing fat levels, since three completely independent variables cannot be derived from one density measurement. This may not be a valid assumption when comparing different sexes, breeds or ages. It is known that all these factors can influence muscle: bone ratios (Berg and Butterfield, 1976). Carcass density has limitations, even in predicting two carcass components. The addition of percent carcass bone as a second independent variable does not substantially improve the prediction of muscle or fat (Fortin *et al.* 1980). For these reasons, the carcass density method of predicting carcass composition was rejected in favour of the sample joint dissection method.

A number of sample joint or partial dissection techniques have been tested in the past. Butterfield (1965) suggested using the radius-ulna and selected shin muscles in conjuction with carcass weight and backfat thickness to predict carcass composition. Marchello *et al.* (1979) found that certain muscles such as *Biceps femoris, Semitendinosis or Psoas major* could be used to predict carcass composition

with a reasonable degree of accuracy. The sample joint selected for this experiment was the 9-10-11th rib joint described by Hankins and Howe (1946). The correlation coefficient between separable 9-10-11th rib lean and the total weight of carcass separable lean was calculated by Cole *et al.* (1960) to be 0.74.

B. METHODS AND MATERIALS

Thirty-eight cull range cows were used in this experiment which began on December 10, 1979. Prior to this date, there had been 41 cows in this group. One cow was shipped to the packing plant suffering from an acute calcium deficiency induced by stress. Two more died of lactic acidosis in an earlier attempt to introduce these cows to a high grain ration. Of the 38 cows remaining, 18 were 3 or 4 years of age (the young group) while the remaining 20 cows were all 6 years of age or older (the mature group). At the start of the experimental period it was visibly apparent that there were large differences among these cows in the level of body fat present. Because of this, the carcass improvement over the feeding period could not be measured by a comparative slaughter trial as was done in experiment 1. A method of objectively rating body condition or fatness in each cow was required so that the improvement that occurred during feeding could be measured individually. An ultrasonic measurement of backfat thickness, taken on the left side at the 12th rib, about 7.5 cm off the midline, was used for

this purpose. The machine used to make the measurement was a "Scanogram (registered trade mark), model 722". This machine, described by Tulloh *et al.* (1973), automatically scanned over the *Longissimus dorsi* muscle, from the midline, down. The results were recorded on "Polaroid (registered trade mark), type 107, Land film", in two dimentional form (cross sectional). Linear measurements made on the photographs were multiplied by 2.54 (scale 1 cm: 1 in) to obtain the actual fat thickness on the animal. In an attempt to eliminate a possible source of error, the same judge was used to interpret all the ultrasonic scans (Miles *et al.* 1972). The first ultrasonic scan had been done a few weeks prior to the start of the trial. Within each age group the cows were ranked from thinnest to fattest. They were then separated into five pens per age group so that the cows in each pen (3 or 4 cows per pen) were all of a similar level of fatness. For each of the eight pens which held four cows, one cow was selected at random for slaughter on day one of the experiment (3 young cows, 5 mature cows). The remaining 30 cows (15 young, 15 mature) were used in the feeding trial.

The diet fed is shown in Table 8. The hay had been harvested in square bales and was fed without any further processing. All of the ingredients except the hay were mixed together to form a concentrate. The diet, as fed, consisted of 9 parts concentrate plus 1 part hay. For the first 24 days feed intake was limited. The intake of concentrate was

Table 8 Composition and Digestible Nutrient Values for Ellerslie Cow Diet

AIR DRY COMPOSITION

Ingredient	Composition (kg/ tonne)	
	Concentrate	Total Diet *a*
Alfalfa-grass hay	-	100.0
Rolled barley	967.0	870.0
Molasses	22.0	20.0
Trace Mineral Salt	2.7	2.5
Limestone	6.1	5.5
Vitamin premix	2.2	2.0
Total	100.0	100.00

ANALYSIS

Dry Matter	-	87.53%
Digestible Energy	-	15.5 MJ/ kg DM
Digestible Protein	-	99.1 g/ kg DM

a 90% concentrate, 10%hay

increased from 6.5 kg/ head/ day (about 1.2% of body weight) on day one to 8 kg/ head/ day by .5 kg/ head/ day increments. After this the daily increases were limited to .25 kg/ head/ day. The cows were held at 9 kg concentrate/ head/ day for 3 days before continuing to *ad libitum* intake. The intake of hay was increased accordingly. In the latter half of the preliminary period, twice a day feeding was used for the concentrate. The entire days allotment of hay was fed in the morning.

The period on full feed began January 3, 1980 and ran for eight weeks. During this time, the feed bunks were checked every morning and sufficient concentrate was added to ensure that the cows had access to this at all times. Once a week, the excess was weighed back so that actual feed consumption could be determined. Throughout the period on full feed, alfalfa-grass hay was fed once per day. The amount fed was based on the voluntary consumption of concentrate in each pen.

Each cow was weighed every second week and ultrasonic backfat scans were taken every four weeks. Height at the hips was measured twice. These height measurments were taken on the dorsal, medial surface between the *tuber coxae*. The heights of all 38 cows were measured on December 6, 1979. The 30 cows used in the feeding trial were measured again on January 3, 1980 (day one of the full feed period). For those cows which were measured twice, the average of the two measurements was used in the analysis.

During the full feed period, a mature cow died. Cause of death was listed as an extensive infection in the throat latch or thoracic inlet area, presumed to be malignant edema. The height and weight data collected from this cow prior to her death were not used in the analysis.

The values for digestible energy and digestible protein (Table 8) were determined using four young bulls, 350 to 450 kg liveweight, which were housed in metabolic crates. The bulls were fed at a level of intake near maintenance. This

was estimated from the equation of Garret *et al.* (1959). The bulls had been consuming the experimental diet prior to being placed in the metabolic crates. Once inside the crates, the bulls were given two weeks to adjust to the crates and the maintenance level of intake. After this initial two week adjustment, daily fecal output was collected and weighed for eight consecutive days. A sub-sample of each days collection was frozen and bulked for subsequent gross energy, nitrogen and dry matter determinations. Because two of the bulls occasionally urinated in the feces collection, it was necessary to keep the collection for these days separate so that N determinations could be done on the uncontaminated material.

Slaughter data were obtained from the eight cow initial slaughter group and the 29 cows that completed the feeding trial. The night before slaughter, all excess feed was weighed back and the water was turned off. The cows were trucked to the packing plant (about a 30 minute trip) and slaughtered before noon. Carcasses were given identification tags on the kill floor as soon as the hides were removed.

After chilling overnight, the following data were recorded by Agriculture Canada graders; rib eye areas, carcass grade, average fat thickness over the rib eye (average of three measurements) and hot carcass weight. In addition, carcass length was measured from the anterior edge of the pubic symphysis to the distal edge of the first thoracic vertebra, by Department of Animal Science personel.

After the carcass measurements were taken, a 9-10-11th rib joint was removed from each carcass. Each joint was trimmed according to the method described by Hankins and Howe (1946) and weighed. They were then wrapped in plastic or wet towels and refrigerated at 0°C until they could be worked on (not more than three days later). All ribs were reweighed upon removal from the cooler and physically separated into muscle, bone and fat.

Statistical Analysis

Only weight gains made during the period on full feed were included in the statistical analysis. It was assumed that weight gains made prior to this were influenced by changing gut contents. The statistical model used is shown in Table 9. These data were analysed as a split plot. Pens and age groups were tested against error(a) and time plus the interactions with time were tested against error(b). The split plot analysis on the repeated measures of average daily gain did not completely take into account the special relationships among time intervals. Because of this, the variation attributable to time and the interactions of time with pens and ages was broken down further by a series of orthogonal contrasts as suggested by Rowell and Walters (1976). This allowed the separation of the effects of time into linear, quadratic and cubic responses, and provided a test for the significance of each.

The analysis of variance for feed consumption and increases in subcutaneous fat were done using modifications

Table 9 Statistical Model for the Analysis of Liveweight Gains in Grain Fed Cows

SOURCE	D.F.	
Age	1	
Pen/ Age	8	
Animals/ Pen/ Age	19*c*	Error(a)
Time Interval	3	
Time x Age	3	
Time x Pen	24	
Time x Animals	57*c*	Error(b)
Total	115	

c degrees of freedom reflect the loss of one animal prior to the conclusion of the experiment

of the same basic model. For feed consumption, data were gathered on a pen basis so pens within age became the error term. For subcutaneous fat, three 4 week intervals (including the preliminary period) were used instead of four 2 week intervals, so the degrees of freedom for all terms in the model that include time were adjusted accordingly.

The analysis of the slaughter data included the eight animals killed in the initial slaughter group. The data for carcass length and live animal height at the hips, hot carcass weight, and rib eye area were analysed by a simple one way analysis of variance using age group as the treatment. The data for rib eye area and hot carcass weight were also analysed by a one way analysis of covariance using

length and average carcass fat thickness over the rib eye as the covariates.

Dissection data from the three rib joints were analysed in a similar fashion. Differences between treatments in rib joint weight, muscle weight, bone weight and muscle: bone ratio were tested by a simple one way analysis of variance. A one way analysis of covariance was used to compare muscle weights between treatments after the data had been adjusted to a constant fat weight and a constant bone weight. The range in fatness that these cows exhibited at slaughter provided an opportunity to examine the response of the dependent variables total rib weight, muscle weight and muscle: bone ratio to fattening. This was done within age groups by homogeneity of regression analysis, using fat weight as the covariate. Student Newman Kuel's test was used for a comparison of dependent variable means at the covariate mean.

C. RESULTS AND DISCUSSION

Backfat thickness, as measured by ultrasonics, has been found to be a good predictor of percent carcass fat in cattle (Tulloh *et al.* 1973). Other methods of estimating body composition in live animals such a total body water estimation (Little and Morris, 1972) or K^{40} counting (Clark *et al.* 1976) are either expensive to perform or else require expensive, specialized equipment. Using backfat thickness to rank the pens made it possible to examine feed consumption

data, which were collected on a pen basis, for possible effects due to body fatness. Although later scanogram measurements ranked the individual cows in a slightly different way, the ranking of the pens did not change.

Feed intake was similar for both age groups (Table 10). As the cows continued to fatten with time, there was no apparent tendency to reduce feed intake although there was both a significant linear ($p<0.05$) and quadratic ($p<0.01$) influence of time interval. These shifts were most likely occurring in response to changing environmental conditions since these cows were housed outside and feed intake was noticed to increase on very cold days and decrease on warmer days. Throughout the experiment the young group outgained the mature group. Over the eight week full feeding period this difference was about .3 kg/ head/ day ($p<0.05$). Both groups averaged 520 kg live weight on day one of the full feed period. As maintenance costs are usually represented as a function of body weight$^{.75}$, the two groups were considered to have equal maintenance requirements at this point in time. Because of the similarity in live weight between the two groups, the ability of the young group to convert an equal amount of feed into a larger liveweight gain (superior feed efficiency) suggests that the weight gained by the young cows contained a lower proportion of fat. On a weight basis, adipose tissue requires more energy to deposit than other tissues due to its low water content and high energy density. With respect to time intervals there was a

Table 10 Average Daily Gain and Feed Consumption for 29 Cull Cows Fed for Eight Weeks

	Dry Matter Intake (kg/head/day)	Average Daily Gain (kg/head/day)	Feed Efficiency (feed/gain)
AGE GROUPS			
Young @520 kg initial live weight	12.56	1.61	7.8
Mature @520 kg initial live weight	12.48	1.29	9.7
standard error	±.463	±.225*a*	-
TIME (WEEKS)			
1-2	11.31	1.26	9.0
3-4	13.08	1.77	7.4
5-6	13.33	1.52	8.9
7-8	12.34	1.28	9.6
standard error	±.278*b*	±.171*c*	-

a $p<0.05$, difference between means
b $p<0.01$, quadratic response to time; $p<0.05$ linear response to time
c $p<0.05$, quadratic response to time

significant ($p<0.05$) quadratic response of average daily gain. This was probably related to feed consumption trends over time. There was no significant effect due to pens. Thus, it appears that the level of body fat had little or no effect on the subsequent weight gains made by these cows or their feed efficiency. Swingle *et al.* (1979), using height to weight ratios as a measure of body condition, concluded that body condition influences rate of gain. This apparent contradiction with the present experiment could have two

possible explanations. First, in their experiment, differences in fat levels were achieved by feeding some cows longer than others. An increase in gut fill at the start of the feeding trial would have given those cows fed for the shortest length of time (the leanest cows) the greatest advantage for average daily gain. Second, in the current experiment most of the cows began the feeding trial in relatively fat condition. If very thin cows had been used there might have been a tendency during the recovery period for certain non-fat tissues to take priority over fat and thus improve the growth rate and efficiency.

It was observed that the variation in average daily gains appeared to be less among cows in the young group compared to cows in the mature group. For example, the slowest growing pen of young cows averaged 1.46 kg/ head/ day, and the fastest growing pen of young cows averaged 1.80 kg/ head/ day, while the averages for the mature pens ranged from 0.85 kg/ head/ day to 1.90 kg/ head/ day. It would appear that older cows quite often show slower rates of gain but this is not an inevitable consequence of maturity.

The rate of ultrasonically measured subcutaneous fat deposition is shown in Table 11. Data were collected during the preliminary adjustment period as well as the eight week full feeding period. There were no significant differences between age groups or among the three time intervals. There was, however, a tendency for the young cows to fatten more slowly than the mature cows and the gains tended to be less

Table 11 Rate of Subcutaneous Fat Deposition for 29 Cull Cows Fed for Eight Weeks

INCREASE IN FAT THICKNESS PER FOUR WEEK PERIOD (mm)[a]	
AGE GROUP	
Young	1.6
Mature	1.9
s.e.	±.16
TIME PERIOD	
Preliminary Period	1.5
Full Feed (weeks 1-4)	1.7
Full Feed (weeks 5-8)	2.1
s.e.	±.28

a None of the differences in this table are significant.

rapid during the preliminary period when energy intake was less. The relationship between these ultrasonic backfat measurements (x) and the carcass fat measurements used for grading (y) was described by the following regression equation:

$$y=1.68 + 1.36x$$

$R^2 = .73$

Standard Error of Estimate = 3.402

The 5.3 mm average increase in live animal backfat thickness (over 12 weeks) corresponded to an average increase of 7.2 mm carcass backfat as measured by the government grader.

From 5 to 7mm is required to ensure an optimum grade

(A1, C1 or D1) regardless of age. The rate of subcutaneous fat deposition determines how long the cattle must be fed to achieve the desired grade. It appears that differences in cow age are unlikely to result in any noticable differences in this respect.

The four cows (from an initial group of 41 cows) which died or became disabled prior to and during this experiment (see Methods and Materials) illustrate how important animal health can be in a feedlot operation. Some feedlot operators believe that death losses in the feedlot are higher for cows than for steers or heifers. A possible reason for this may be the large appetites shown by these cattle, which makes them susceptible to problems such as lactic acidosis. Cattle in lean condition are more susceptible to acidosis problems than previously well nourished cattle (Slyter, 1976). At least three weeks are recommended to adapt yearling heifers to *ad libitum* grain intake after an all roughage diet (Tremere *et al.* 1968). From this experiment, it would appear that cows require a similar length of time. When adaptation time is limited, replacing some of the grain in the diet with other high energy feedstuffs may help (Elam, 1976). When feeding grain *ad libitum*, even a low level of roughage, as was used here, may be helpful in reducing digestive upsets (Eadie and Mann, 1970).

Average fat thickness over the rib eye (average of three measurements) ranged from 0 mm to 25 mm for carcasses of the young group and 3 mm to 36 mm for the mature

carcasses. Because of the variation in fatness, neither live weight nor hot carcass weight accurately reflected the differences in body size due to maturity, and there were no significant differences (Table 12) ($p>0.05$). A better indication of lean body size was carcass length. For this trait the young group was significantly ($p<0.05$) shorter than the mature group. The difference, of about 5 cm, represents the growth that must occur before full maturity is reached. These were not the same results that were obtained when live animal height at the hips was measured. At 127 cm in height, the young group were as tall as the mature group. This suggests that growth in height was complete before growth in length. Russel (1975) obtained similar results with Ayrshire cows. He found that "sacrum height" matured earlier than body length. Jones *et al.* (1978*b*) found that bones in the limbs were earlier maturing (lower growth coefficients) than the thoracic and lumbar vertebrae.

Despite their smaller skeletal size, mean rib eye area was 82.1 cm^2 for the young cows and 75.2 cm^2 for the mature cows. These were not significantly different ($P>0.05$).

The analysis of covariance used here was similar to that done in experiment 1 except that average fat thickness was included as a covariate. This addition was thought necessary because of the differences in average fat thickness between groups and among animals within groups.

Table 12 Live Animal and Carcass Mearsurements for 37 Cull Cows

	Young	Mature	S.E.	Significance
ANALYSIS OF VARIANCE				
Hot Carcass Weight(kg)	341.9	314.6	±11.48	NS
Live Animal Height at the Hips(cm)	126.8	125.3	±.78	NS
Carcass Length(cm)	133.8	138.7	±.79	**
Rib Eye Areas(cm^2)	82.1	75.2	±2.55	NS
ANALYSIS OF COVARIANCE *a*				
Hot Carcass Weight(kg)/ /fat, length	346.4	310.4	±7.46	*
Rib Eye Areas(cm^2)/ fat, length	82.3	75.0	±2.60	NS

NS non-significant, $p>0.05$
*,** $p<0.05$, $p<0.01$
a tested at the covariate means; fat thickness=16.2 mm carcass length = 136.3 cm

There have been differences in opinion on the exact relationship between fat growth and muscle growth. Using younger cattle, Guenther *et al.* (1965) reported that a high plane of nutrition resulted in fatter cattle and increased muscle: bone ratios compared to a moderate plane of nutrition. In contrast to this, Callow (1961) found no effect of plane of nutrition on muscle: bone ratio. The differences may be related to the end point of the experiment. Muscle:bone ratios increase with age (developmental growth) as well as fatness. When comparisons

were made on a constant weight basis, where the youngest animals had the most fat, the two effects tended to cancel out. Berg and Butterfield (1966) concluded that, when carcass weights were equal, there was no effect of fatness on muscle: bone ratio. At least part of the increase in muscle mass that accompanies fattenning is due to an increased weight of intramuscular fat within the muscle (Johnson and Pryor, 1974).

Unlike experiment 1, where the effect of slaughter group explained most of the differences in carcass fatness among individuals, in this experiment the covariate fat thickness was responsible for adjusting data within an age group.

The analysis of covariance showed that when differences due to length and fatness were removed, the young group still had significantly heavier carcasses ($p<0.05$). Both covariates were significant ($p<0.05$) with a 1 mm increase in fat thickness corresponding to 6.1±.71 kg (±s.e.) additional carcass weight and 1 cm of carcass length equal to 4.0±1.40 kg carcass weight. The adjusted rib eye areas were not significantly different at the 5% level. Only the covariate fat thickness accounted for a significant amount of the variation in rib eye area, however, both were left in the analysis because of the presumed relationship between rib eye area and length (experiment 1). The slopes of the covariates indicated that a 1 mm increase in fat thickness resulted in a .79±.248 cm^2 increase in rib eye areas and a 1

cm increase in carcass length produced a $0.4 \pm .49\ cm^2$ increase in rib eye area.

The difference in trimmed three rib joint weight between the age groups was not statistically significant although the young group averaged almost 400 g more than the mature group (Table 13). The large standard error associated with total rib weight was probably the result of the large variation in fat content among cows. Joints from the young group ranged from 772 g to 3361 g (average 2524 g) total separable fat while joints from the mature group ranged from 672 g to 4706 g (average 2171 g) total separable fat. Bone weight was 86 g ($p<0.01$) heavier in the mature group indicating that developmental growth had progressed further in this group. In spite of the increased bone in the mature cows, the weight of muscle present was no greater than that present in the young joints, leading to lower ($p<0.01$) muscle: bone ratios. By adjusting rib joint weights to a constant level of separable fat, the means for the two age groups were very similar. The same held true for muscle weights, adjusted to a constant level of fat. The homogeneity of regression tests were not able to detect any significant ($p>.05$) differences between age groups, which indicated that the amount of muscle laid down in response to increasing fatness was similar in the two groups. However, while the homogeneity of regression test was not significant, the direction of the results, presented graphically in Fig. 1, were of interest. The suggestion here

Table 13 Separation of Three Rib Joints into Muscle, Bone and Fat

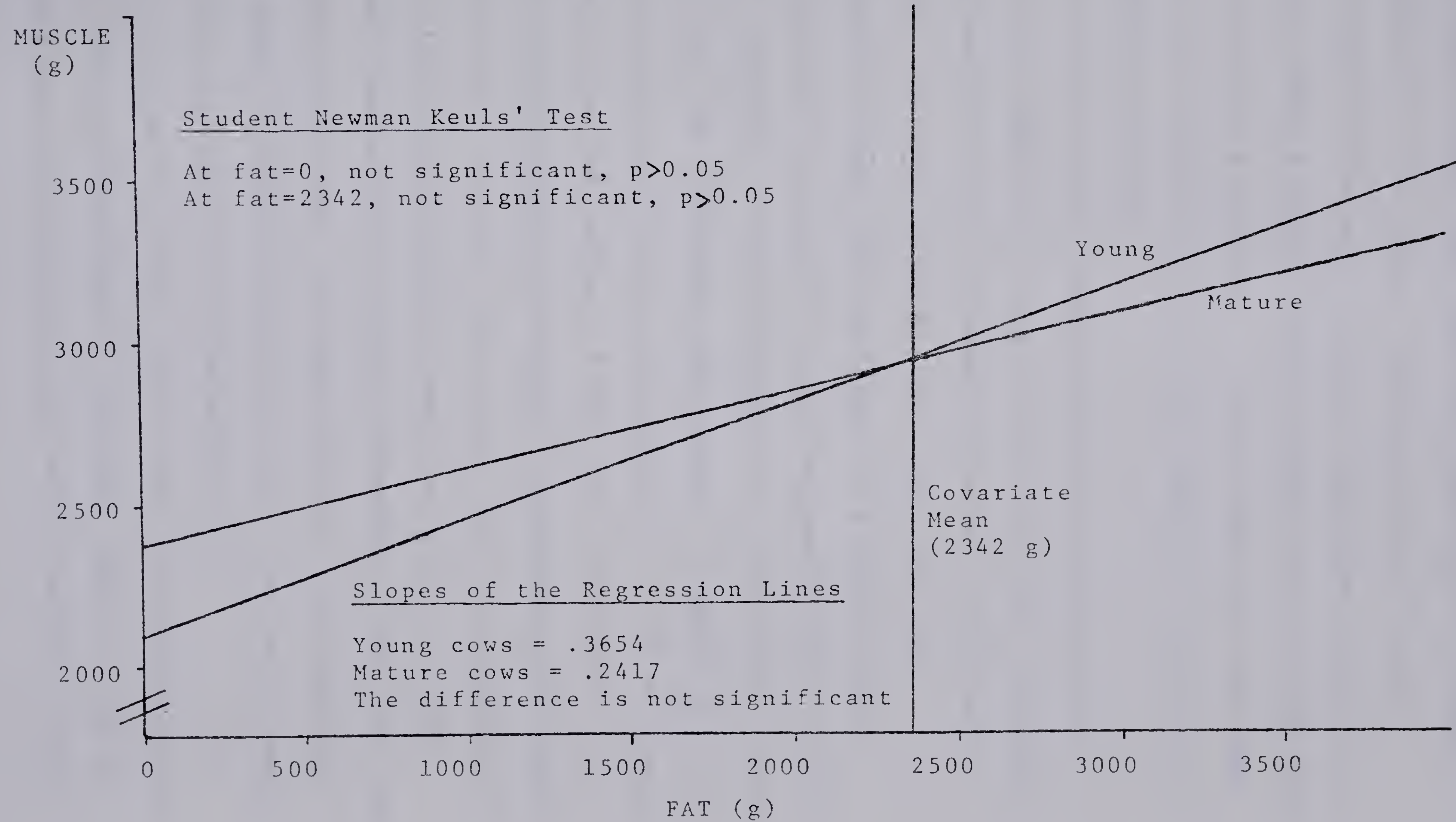
	Young	Mature	S.E.	Significance
ANALYSIS OF VARIANCE				
Total Rib Weight(g)	6364	5991	±310.1	NS
Bone Weight(g)	770	856	±22.3	**
Muscle Weight(g)	3025	2908	±97.0	NS
Muscle:Bone ratio	3.96	3.40	±.098	**
ANALYSIS OF COVARIANCE *a*				
Rib Weight(g)/ fat weight *b*	6105	6215	±90.8	NS
Muscle Weight(g)/ fat weight *b*	2959	2950	±76.9	NS
Muscle Weight(g)/ bone, fat weight	3077	2846	±71.0	*

NS non-significant, $p>0.05$
*,** $p<0.05$, $p<0.01$
a tested at the covariate means; 2342 grams fat, 814 grams bone
b each age group adjusted along separate regression lines

was that at low levels of fat, muscle weight was greater in the mature cows (and muscle: bone ratios were similar). During grain feeding, muscle tissue in the young cow responded more rapidly. By the time the cows became obese, muscle weights were greatest in the young animals and muscle: bone ratios were substantially higher. From this figure, it appears that age had a far greater influence on maximum muscle size than minimum muscle size.

Figure 1

The Effect of Increasing Fatness on the Muscle Weights in Rib Joints from Cull Cows of Different Ages



When bone weight was added as a covariate, the mean muscle weight for the mature joints was significantly ($p<0.05$) less for the mature group. This added weight to the conclusions drawn from the simple carcass measurements taken in this study and experiment 1. All of the covariates used accounted for a significant ($p<0.05$) amount of variation in the dependent variable.

From these results, some conclusions can be drawn regarding the commercial value of this rib joint. Assuming constant levels of fat, the amount of muscle (lean meat) present per rib joint would be relatively constant regardless of cow age. The purchaser of a joint from a mature cow would be required to purchase more bone to obtain this meat compared to the purchaser of a joint from a three year old cow. The difference would amount to about 20 to 30 g extra bone per kg of muscle, or roughly 2 to 3% more waste depending on the fat content of the rib. Fat content would still be the most important factor in determining the amount of waste in the rib joint. The b value for the covariate fat weight on total muscle weight, when the effects of bone weight were removed, was $.18 \pm .056$. Therefore, over the range of fatness studied here, for every 100 g of fat deposited in the rib joint during the feeding period, total muscle weight in the rib joint was only increased by 18 g.

It is the beef carcass, and not the rib joint which is the basic unit of production in the beef industry. But to extend this type of analysis to the entire carcass, it is

first necessary to extrapolate carcass composition from rib joint composition. As there have been no equations specifically derived from cow carcasses for this purpose, the equations of Hankins and Howe (1946) for steers and heifers must suffice. The results obtained from the analysis of covariance (covariates were fat weight and bone weight), after this manipulation of the data, were similar to those which were obtained from the analysis of the raw rib data. The young cows had an adjusted mean muscle weight of 187±2.9 kg compared to 174±2.9 kg for the mature group ($p<0.01$). The slope for the covariate "fat" was .115±0.0607 or, for each kg of fat deposited only .115 kg of muscle was deposited. This figure for muscle growth seemed somewhat low but there were very few cows in poor condition slaughtered for this experiment. Cows in the initial stages of realimentation might have laid down a higher proportion of muscle relative to fat.

In this experiment, the faster weight gains seen in younger cows were associated with a greater efficiency of feed utilization. Neither cow age nor condition had any apparent influence on feed consumption. This implied a greater proportion of lean growth in the younger females. The most likely explanation is that continuing bone growth in the young cows increased the potential for lean rather than fat growth. It is also possible that the proportion of lean meat (protein plus water) deposited for each unit of fat laid down may have been slightly higher for the younger

cows. Overall, in terms of liveweight growth, carcass lean growth and feed efficiency, the young cows were far more productive than the mature cows.

IV. EXPERIMENT #3: BONE GROWTH IN CULL COWS

A. BACKGROUND

Because of the large increase in carcass length that apparently occurred in experiment 1 as time on feed increased, it was decided to further investigate the effects of grain finishing on bone length growth in cows of different ages. By measuring bone growth during the early stages of a grain feeding period, and again after the cows reached *ad libitum* intake, any marked increase in the rate of bone growth due to the high energy feed should be detected.

One way to measure the growth of a particular tissue or part of the body is to run a comparative slaughter trial (as was done in experiment 1). The difference between the means for the control group and a group slaughtered at a later time represents the growth that occurred during this time interval. An alternative is to slaughter serially and run regression analysis. In this case the slope of the regression line represents the rate of growth. In either case, unless large numbers of cattle are used, variation in size among individuals makes a precise measurement of growth rate difficult. This is especially true when short time intervals are used. The technique described in this experiment is capable of measuring the growth that occurs in each individual animal over a specific time interval and

thereby eliminates this problem.

Increases in bone length occur at the epiphyseal plates within the bone. Cell division occurs within the distal edge of the cartilage growth plate. Moving proximally from this "proliferative zone" the age of the cartilage cells increases. As time progresses these cells hypertrophy ("hypertrophic zone") and then degenerate while the intercellular matrix becomes calcified ("calcified zone"; Pritchard, 1974). Eventually this calcified cartilage is resorbed by osteoclasts and replaced by true bone. This addition of new material to the distal side of the cartilage growth plate and the conversion of the older material on the proximal surface to true bone results in the elongation of the diaphysis. The older this bone tissue becomes, the more new bone is formed between it and the cartilage growth plate.

In this experiment, sites of ossification were labelled *in vivo* so that the subsequent increases in bone length could be measured at the time of slaughter.

B. METHODS AND MATERIALS

Fifteen crossbred beef cows were used for this experiment; 5 two year olds, 5 three year olds and 5 four year olds. One of the four year olds was removed early in the experiment due to a problem unrelated to the treatment (hardware disease). "Terramycin" (Trademark, Pfizer Co. Ltd.), an oxytetracycline was used to produce the *in vivo*

label. It was diluted with sterile saline to five times its original volume and administered in a single jugular infusion to provide 15 mg oxytetracyline per kg body weight. This procedure was repeated five weeks later and the cows were slaughtered after a further five weeks. The cows were introduced to a high grain ration during the first five week period (the same ration that was used in experiment 1) and were fed *ad libitum* during the second five week period.

The distal radius was chosen because it is easily removed from the carcass.

Following slaughter and overnight chilling, the distal radius was removed and longitudinally split. One of the resulting halves was clamped with the cut surface facing upward. A camera and two ultraviolet lamps (366 nm, 115 volts, .14amps) were mounted above the bone. All photographs were taken with black and white film (A.S.A. 125). Each bone was photographed twice. The first exposure, made under visible light, recorded the present position of the growth plate within the bone. The second exposure, made under ultraviolet light, recorded the position of the yellow-green fluorescent lines demarcating the zones of active bone formation at the times of labelling. Under ultraviolet light, an ultraviolet blocking filter (to block reflected ultraviolet light) and a medium yellow filter (to block visible blue light emitted by the lamps) were fitted to the camera. Printing on 20 cm x 25 cm paper gave a linear magnification of about 3 times actual size.

C. RESULTS AND DISCUSSION

The use of tetracyclines for *in vivo* labelling of actively ossifying bone has been discussed by Frost (1968). The method has been used to quantify bone growth in length and circumference, particularily in rats (Tapp, 1966). In cattle and horses, the boundaries between labelled and subsequently formed bone are quite distinct due to the rapid removal of tetracycline from the bloodstream (MacCallum *et al.* 1972).

Staining bone with tetracycline is similar to the classical staining techniques using madder (Rubia tinctorum) root (Payton, 1932), except that the labelling substance is given in one quick infusion rather than including it in the feed. Bone growth can also be measured radiographically after the insertion of metal markers into the shaft (Sissons, 1953; Bisgard and Bisgard, 1935). This method, however, requires a surgical operation for each bone that is to be measured. Tetracycline, being relatively non toxic gives a minimum of interference with the growth of the experimental animal.

Examples of these photograghs are shown in Plate 1 (visible light) and Plate 2 (ultraviolet light).

As shown in Plate 2, the fluorescent line had a distinct distal boundary but no distinct proximal boundary. This reflected the pattern of ossification activity that existed at the time of labelling. The distance from the

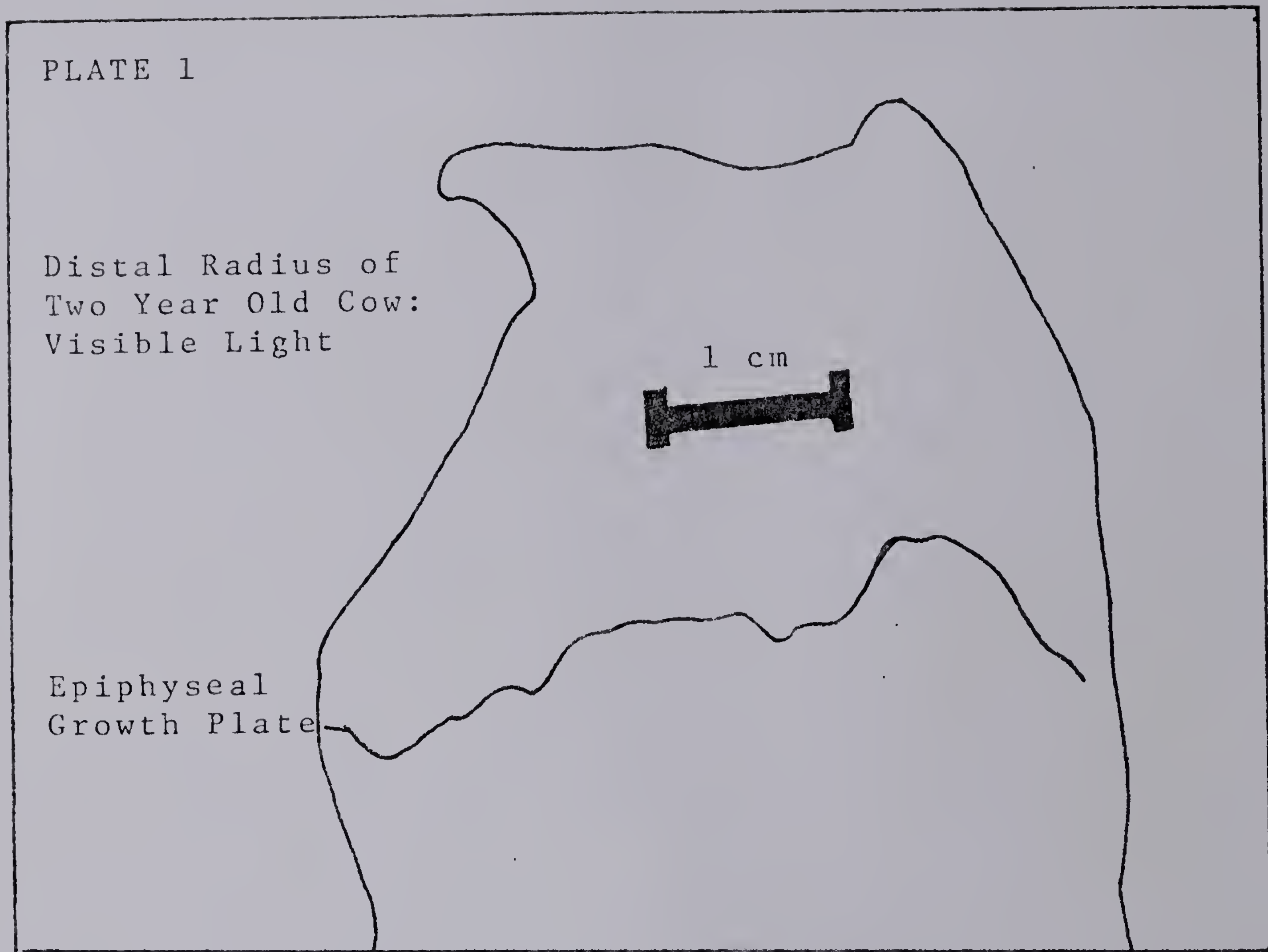


PLATE 1
Distal Radius of
Two Year Old Cow:
Visible Light
1 cm
Epiphyseal
Growth Plate

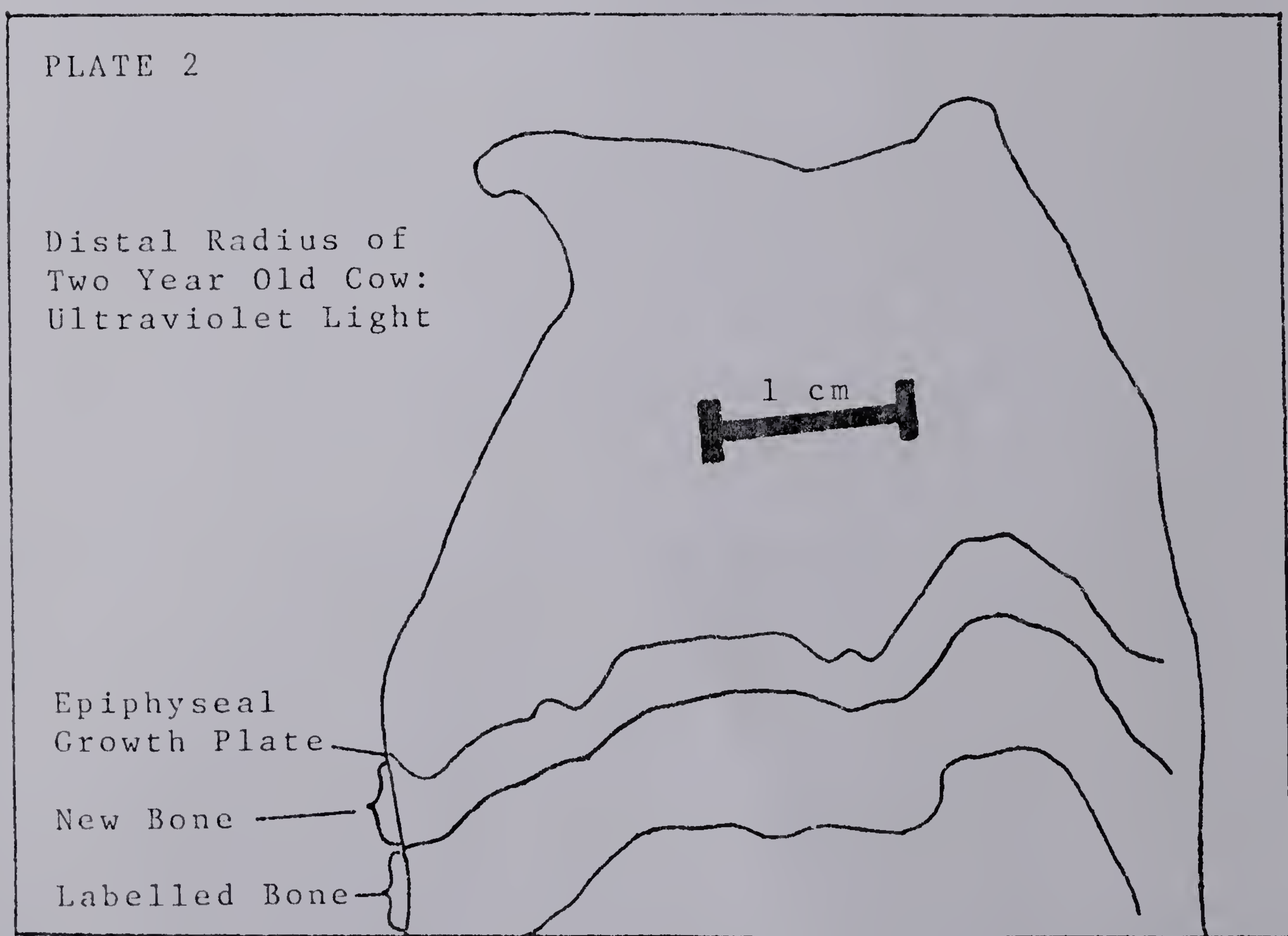
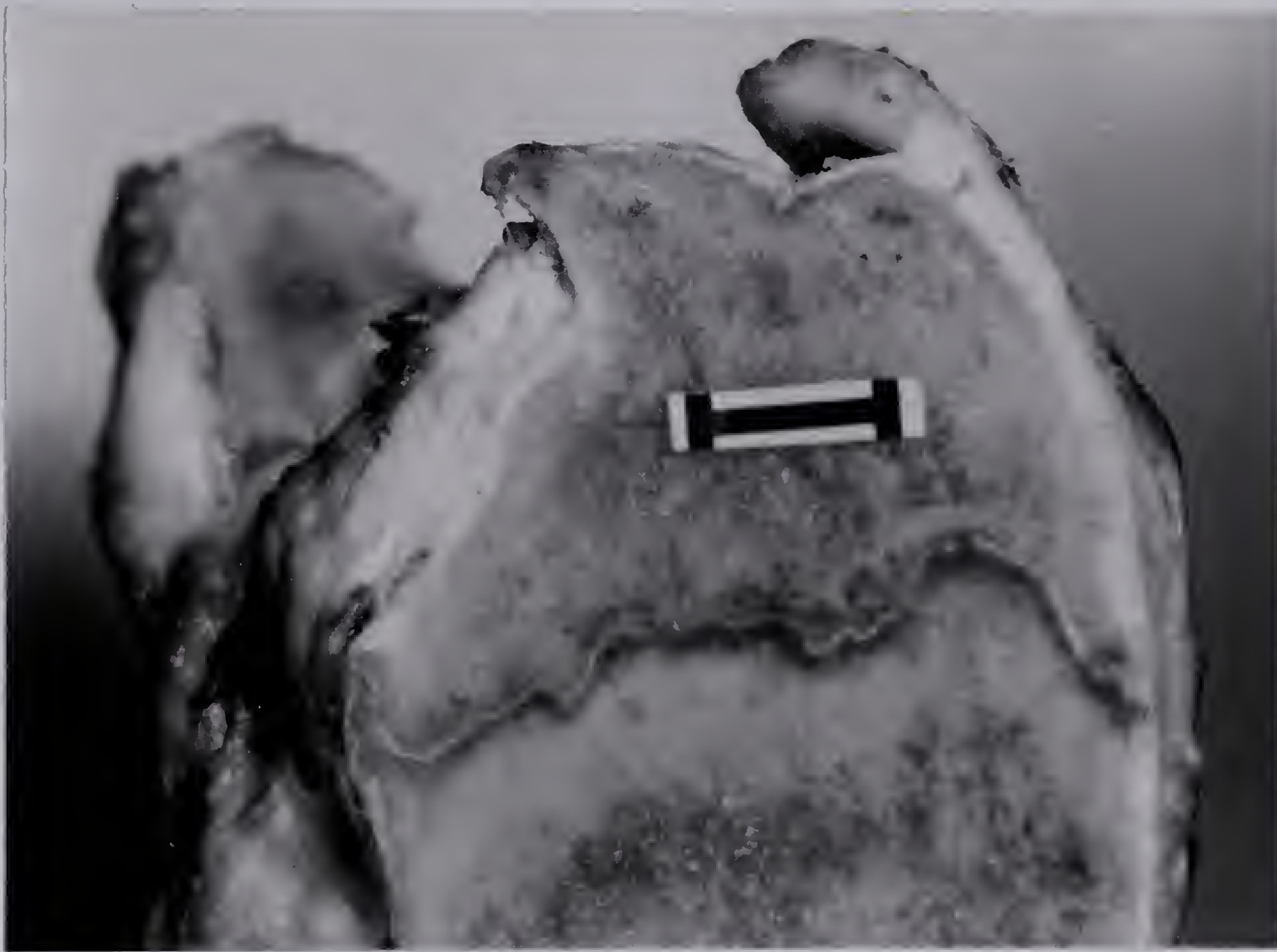


PLATE 2
Distal Radius of
Two Year Old Cow:
Ultraviolet Light
1 cm
Epiphyseal
Growth Plate
New Bone
Labelled Bone



distal edge of the first fluorescent line to the distal edge of the second line was the increase in length during the first five weeks. The distance from the distal edge of the second fluorescent line to the proximal edge of the growth plate was the increase in length during the second five week period. The width of the second fluorescent line was sufficient to cause some overlap between the two labels. As a result, it was easier to measure the distance from the second label to the growth plate than from the first label to the second (see Plate 2).

No increase in length occured in the distal radius of the four year old cows. The absence of a tetracycline band next to the growth plate indicated that closure (fusion of the epiphysis to the diaphysis) of the epiphyseal growth plate was already complete when the tetracycline infusions were made. In the case of the three year old cows, there was a visible band of new bone between the growth plate and the second label. The rate of growth, however, was not sufficient to clearly separate the two labels. In the two year old cows, a more rapid rate of bone growth led to a greater distance between the growth plate and the second label. Furthermore, in three of the five cows in this age group, there was sufficient separation of the fluorescent lines to allow a measurement of growth in both five week periods.

A measurement between the label and the growth plate may be less accurate than a measurement between two labels

because at the growth plate the zone of resorbtion and ossification (formation of true bone) is permanently labelled while the zone of calcification (formation of calcified cartilage) is not (MacCallum *et al.* 1972). With the naked eye it is impossible to identify the different zones within the epiphyseal growth plate although the error introduced here is probably very small.

The measurements taken for the second five week period are summed up in Table 14. In the three cases where both tetracycline labels could be identified, the growth rate in the first five weeks was similar to growth in the second five weeks. This suggests that the high grain feeding was not significantly increasing the rate of growth in the radius. The results show the expected decline in growth rate with age. According to Sisson and Grossman (1953), closure of the epiphysial cartilage plate in the distal radius occurs between 3 1/2 and 4 years of age. This is supported by these results since closure had occurred in all four year old cows.

The differences in the growth rates of bone length among different agé groups do not necessarily point to proportional differences in lean body growth rates (on a weight basis) among age groups. Bone weight is not directly proportional to bone length, but to some higher power of bone length (most likely close to length^3). Because of this, bone length will mature earlier than bone weight. Also, Jones *et al.* (1978*b*) have found that the radius-ulna is

Table 14 Growth in Length at the Distal Radius in 14 Young Cows Five Weeks Before Slaughter

Number of Cows	Age Range at Slaughter (days)	Growth Rate (mm/day)	SD
5	696-732	.0732	.02680
5	1068-1093	.0205	.00979
4	1420-1448	0	-

SD standard deviation

early maturing (growth coefficient = .92) relative to the total skeleton. Furthermore, bone, measured on a weight basis is earlier maturing than muscle tissue (Berg *et al.* 1978, Palsson 1955). Therefore, it is possible that a slow rate of bone length growth in a large (older) cow could support the same rate of muscle growth (weight) as a fast rate of bone length growth in a smaller (younger) cow. This may help explain why the three and four year old cows in experiment 2, which were close to mature size, still had a substantial advantage over the mature cows in feedlot performance.

V. THE PROFITABILITY OF COW FEEDING

A. BACKGROUND

Although most slaughter cattle are sold on a liveweight basis, trading slaughter cows in this way presents some unique problems. Besides looking at body condition, the possibility of pregnancy and the physiological maturity of the cow need to be considered when estimating the value of the animal. Selling cows "railgrade" may be the easiest way to ensure that the price received reflects the actual slaughter value of the animal. The government market reports do not include railgrade prices. However, in the past, the value of animal by-products (such as the hide, tallow, edible offals and pharmaceuticals) has been approximately equal to the packer's operating costs and profit (Moncrieff, 1978). Allowing for small fluctuations in the value of these by products, the railgrade price should follow the carcass wholesale price very closely.

At culling, some important decisions must be made regarding the fate of the cull cows. One of these decisions is whether or not to feed grain to these cows before marketing. Price and Berg (1981) estimated the feeding costs and the increase in carcass value for 18 cull beef cows fed during November and December of 1978. They concluded that cows of all ages could have been profitably fed although the profit margins were highest for the youngest cows. Since

that time, however, prices have changed considerably. In addition, if cows are to be grain fed, a decision must be made regarding the duration of the feeding period. The following analysis was conducted to examine the effect of cow age and length of time on feed on the potential profitability of cow feeding in 1980.

B. METHODOLOGY

All of the experimental data used for this analysis were taken from experiment 1, as the condition of the cows in this experiment resembled a practical situation more closely than in the second experiment. Feed prices (Table 15) were based on University purchases from February until June of 1980. Feed costs (feed consumption multiplied by the cost of the ration) were calculated for each of the eight week feeding periods, and the entire 16 week period.

The distribution of carcass grades within each age x slaughter group was tabulated as shown in Table 16. The carcass prices used were based on the Montreal wholesale carlot prices reported by Agriculture Canada (1980) and Alberta Agriculture (1980*a*) for the first week in March, 1980. These prices were for youthful steer carcasses and more mature cow carcasses. Agriculture Canada (1980) also reported the Alberta wholesale price for A1 steers. "Alberta railgrade prices" were estimated as follows:

1. Montreal wholesale prices for youthful steers were discounted by 3¢/ lb. (6.6¢/ kg) to arrive at a heifer

Table 15 Cost of Kinsella Cow Ration

	kg/tonne	@$/tonne	total cost $/tonne
INGREDIENT			
Barley	620	108.00	66.96
Rolled Oats	200	97.50	19.50
Alfalfa Pellets	100	110.00	11.00
Rapeseed Meal	58	207.00	12.01
Calcium Carbonate	10	59.00	0.59
Dicalcium Phosphate	5.2	366.00	1.90
Vitamin Premix	2.6	318.00	0.83
Trace Mineral Salt	2.6	136.00	0.35
Molassas	1.6	160.00	0.26
Processing	-	-	5.00
Total	1000.0	-	118.40

price. This is the approximate differential that existed between heifers and steers later in the year, when A1 heifer prices were available.

2. Alberta prices for youthful heifers, intermediate aged cows and mature cows were obtained by applying the differential between Alberta and Montreal for A1 steers to the other grades.

3. Within the marketplace, light carcasses and overweight carcasses would also have been discounted within the A and B grades. In the first slaughter group, all of the grade A and B carcasses were less than 500 lbs. (227 kg) so these prices were discounted by 2¢/ lb. (4.4¢/ kg). In the second slaughter group, 11 of 17 grade A and B carcasses were less than 550 lbs (249 kg). These prices

Table 16 Distribution of Carcass Grades for 87 Cull Cows

	A1	A2	A3	B1	C1[a]	C1[b]	C2	D1	D2	D3	D5	Total
YOUTHFUL AGE												
Slaughter												
#1	2	-	-	5	6	-	2	-	-	-	2	17
#2	9	2	-	5	-	-	2	-	-	-	-	18
#3	7	5	2	2	-	2	-	-	-	-	-	18
INTERMEDIATE AGE												
Slaughter												
#1	-	-	-	-	3	1	-	-	-	-	2	6
#2	-	1	-	-	-	5	-	1	1	-	-	8
#3	-	-	-	-	-	4	-	2	-	-	-	6
MATURE AGE												
Slaughter												
#1	-	-	-	-	-	-	-	2	2	1	-	5
#2	-	-	-	-	-	-	-	2	2	-	-	4
#3	-	-	-	-	-	-	-	5	-	-	-	5
Total	18	8	2	12	9	12	4	12	5	1	4	87

a Youthful maturity class
b Intermediate maturity class

were discounted by 1¢/ lb. (2.2¢/ kg). Of the grade A and B carcasses in the third slaughter group, 1 was less than 550 lbs (249 kg) and 4 were over 700 lbs (317 kg). These prices were also discounted by 1¢/ lb. (2.2¢/ kg). The "Alberta railgrade prices" estimated in this way, are shown in Table 17.

Table 17 Alberta Railgrade Carcass Prices
(March 6, 1980)

heifers and cows

	$/lb	$/kg
CARCASS GRADES		
A1,2*a*	1.2625 1.2525	2.78 2.76
A3*a*	1.1625 1.1525	2.56 2.54
B1*a*	1.2125 1.2025	2.67 2.65
C1 (MI)*b*	1.1925	2.63
C1 (MII)*c*	1.0525	2.32
C2	1.0525	2.32
D1	1.0225	2.25
D2	1.0225	2.25
D3	1.0525	2.32
D5	1.0525	2.32

a first value used for slaughter groups 2 and 3, second value used for slaughter group 1.
b Youthful maturity class
c Intermediate maturity class

An "average carcass price" was calculated for each group by multiplying the Alberta wholesale prices by the proportion of cattle falling into those grades and summing the products. To obtain a "total return" for each age x slaughter group, hot carcass weight was multiplied by the

average carcass price. "Added return" for each eight week period was the increase in total return during that period. "Net return" was the total return for the appropriate age group after 8 or 16 weeks feeding, less the return from the initial slaughter group and the total feed cost. "Added net return" was the increase in the net return during each eight week period.

C. DISCUSSION

Most of the culling in Western Canadian beef herds is done in late fall, at weaning. If a sixteen week feeding period is used the slaughter date will be close to the first week in March. In this analysis, the first week of March, 1980 was used as the source of carcass prices for all slaughter groups so that market fluctuations would not give one group an advantage over another. In practice, even if shorter feeding periods are used, it may pay to maintain the cows on low quality roughage and delay grain feeding until early in the new year. Historically, cow prices tend to follow a cyclical pattern throughout the year. Slaughter cow prices are usually higher in March, April and May than earlier in the year (Alberta Agriculture, 1980*b*).

Table 18 shows feed consumption and costs for the 87 cull cows in experiment 1. From the results of experiment 2, it is probable that cows in different age groups consumed similar amounts of feed (at least those cows 3 years of age or more). A total return of $81.93 after eight weeks feeding

Table 18 Calculation of Feeding Costs for 87 Cull Cows Fed for 0, 8 or 16 Weeks

	FEED CONSUMPTION		FEED COST @11.84¢/kg	
TIME PERIOD	Total (kg)	Added (kg)	Total ($)	Added ($)
Control	0	-	0.00	-
8 Weeks	692	692	81.93	81.93
16 Weeks	1480	788	175.23	93.30

and $175.23 after 16 weeks, was needed to offset the cost of feeding. In both eight week periods, the added feed cost was similar.

Hot carcass weight, average carcass price/ kg, total returns and net returns are shown in Table 19. The first eight weeks of feeding increased the average carcass price by 13¢/ kg for the youthful cows. Additional feeding did not improve the average carcass price for these youthful cows. Average carcass price for the intermediate and mature cows was not improved by feeding. The drop in price for the intermediate group after eight weeks feeding was due to the fact that fewer carcasses fell into the youthful carcass grades. This was probably unrelated to the high grain feeding. Only the mature cows failed to show a positive net return after eight weeks of feeding. The mature cows also showed the smallest net return after 16 weeks feeding. For all three age groups, the net return was greater after 16

Table 19

Carcass Weight and Value for Cull Beef Cows of Three Different Ages and Fed for 0, 8 or 16 Weeks

(March 6, 1980)

	Total Carcass Weight (kg)	Added Carcass Weight (kg)	Ave. Price ($/kg)	Total Return ($/head)	Added Return ($/head)	Net Return ($)	Added Net Return ($)
YOUTHFUL (2,3 years of age)							
Slaughter							
Control	183	-	2.58	472.14	-	-	-
8 Weeks	226	43	2.70	610.20	138.06	+56.13	+56.13
16 Weeks	299	73	2.69	804.31	194.11	+156.94	+100.81
INTERMEDIATE (4,5 years of age)							
Slaughter							
Control	211	-	2.48	523.28	-	-	-
8 Weeks	271	60	2.36	639.56	116.28	+34.35	+34.35
16 Weeks	340	69	2.30	782.00	142.44	+83.49	+49.14
MATURE (≥6 years of age)							
Slaughter							
Control	263	-	2.26	594.38	-	-	-
8 Weeks	284	21	2.25	639.00	44.62	-37.31	-37.31
16 Weeks	346	62	2.25	778.50	139.50	+8.89	+46.20
ALL AGE CLASSES [a]							
Slaughter							
Control	203	-	2.50	508.22	-	-	-
8 Weeks	246	43	2.55	626.61	118.36	+36.46	+36.46
16 Weeks	316	70	2.53	798.44	171.83	+114.99	+78.53

[a] Weight and price data are weighted averages of the other three age classes

weeks feeding than after eight weeks feeding. For the entire herd, the net return was $36.46 after eight weeks and $114.99 after 16 weeks.

Overall, the second eight week period appeared to be much more profitable than the first eight weeks. This was due to the large increase in carcass weight that occurred during the second eight weeks. Average carcass price, which in this analysis was mainly dependent on carcass grade, changed very little between the second and third slaughter groups. This increase in added net return was especially large for the mature cows which went from a -$37.31 added net return (loss) in the first eight weeks to a +$46.20 added net return (profit) in the second eight weeks. For the entire herd, the added net return in the second eight weeks was more than double what it had been in the first eight weeks ($36.46 in the first eight weeks, $78.53 in the second eight weeks). Therefore, to maximize the net return per unit of time, it was necessary to feed during the second eight week period.

The estimated ration cost used here is substantially greater than Price and Berg (1981) estimated for a similar ration in 1978. (Up to $118.40/ tonne from $77.20/ tonne). However, relatively good predictions of feed prices can usually be made at the start of a two or three month feeding period. Small fluctuations in feed prices have a relatively small effect on total costs. In this example, if feed prices were underestimated by $10/ tonne, the resulting increase in

total feed costs/ head would be about $7.00 after eight weeks. In a large feedlot, feed grain prices could be hedged on the futures market to lock in feed costs.

In this analysis, net return was defined as the increase in carcass value over the feeding period, less the feeding costs. The actual profit realized could be less than the net return over feed costs since feeder cows might sometimes be purchased for more than their actual slaughter value. Also, yardage, veterinary costs, death loss and marketing costs could lower profit, depending on the circumstances.

That the mature cows were less profitable than the other groups was due to their poorer performance in the feedlot and the lower prices obtained for their carcasses. The price spread between the youthful and mature carcasses may change over time. The number of cows slaughtered relative to steers tends to increase during the liquidation phase of the cattle cycle (Pugh, 1978). Also, imported beef from Oceanic countries competes with domestically produced cow beef while leaving prices for youthful, finished beef relatively unaffected (Williams and Stout, 1964).

It can be seen from Table 19 that a small change in the carcass price would have caused a relatively large shift in carcass value. For example, if carcass prices at the end of the feeding period had been underestimated by only 10¢/ kg, the net return would have been over $25/ head lower than expected for those groups fed for eight weeks and over $30/

head lower for those groups fed for 16 weeks. Conversely, small shifts upward in the carcass price would have substantially increased the net return.

The carcass value at the start of the feeding period depends on the management system and environmental conditions during the previous summer and fall. Therefore, when feeding cows in a practical situation, it may be necessary to feed for shorter or longer periods of time to achieve results similar to those shown here.

It was concluded from this analysis that cows five years of age or less could have been profitably fed in 1980. In spite of the increased number of A2 carcasses and the decreased number of A1 carcasses, the second eight week period was more profitable than the first eight week period. If the experiment had continued, an increased number of A3, A4 and D4 carcasses would probably have lowered the net return. It was also concluded that feeding mature cows was unlikely to be profitable under these conditions.

VI. GENERAL DISCUSSION AND CONCLUSIONS

In this study, the feedlot performance of cull range cows was evaluated under conditions similar to those which might be found in a commercial feedlot. The cows used in these experiments consistently gained over a kilogram per day. The amount of feed eaten per head per day frequently surpassed 3% of body weight and occasionally surpassed 4% of body weight. Over the range of fatness studied in these experiments there was no evidence to suggest that the absolute amount eaten was in any way dependent upon body condition. In experiment 1, the rate of live weight gain appeared to decline sharply as the feeding continued, however part of the initial weight gain was likely due to increased gut fill. In experiment 2, actual rates of live weight or carcass weight gain changed very little as time progressed. Also in experiment 2, cow age was shown to have a large influence on the rate of weight gain in the feedlot. The younger cows gained weight faster and with greater efficiency than the mature cows.

The cows used for these experiments represented different stages of development. Some had not yet completed developmental growth while others were fully mature.

The results from the carcass data indicated that bone continued growing in the younger cows up to about five years of age. Within an age group there was a very definite relationship between the amount of bone and the amount of

muscle, so this growth of the skeletal system must have been accompanied by an increase in muscle mass. This type of growth was termed "developmental growth" and it was responsible for the higher lean body growth potential in the younger cows. If it were excluded from the total carcass gain, then there appeared to be very little difference among cows of various ages in the relative amounts of muscle and fat laid down during grain feeding. This second type of growth was termed "catch-up" growth and although it included both muscle and fat, the fat appeared to be the largest component. This could be partly related to the excessive levels of fat on most cows in experiment 2 and may not always be true in cows of leaner condition.

Increasing cow age had an adverse effect on muscle: bone ratios after maturity was reached. For young cows that had not yet reached maturity the opposite response of muscle: bone ratios to increasing age was expected since muscle is known to be later maturing than bone (Palsson, 1955; Berg *et al.* 1978). Investigations into the compensatory growth phenomenon have concluded that muscle indefinitely retains the ability to recover its maximum size when nutrition permits (Yeates, 1964). However, the degree and length of the nutritional insult which these cows were subjected to, is something which is difficult to duplicate in controlled studies on realimentation. Therefore, it was not possible to determine if the observed differences were due to a loss of muscle with age or an impairment in the

ability to recover muscle mass with age. There is a third possibility that the young cows were not representative of the mature cows at a younger age. This factor could be termed "reproductive competency". It arose because of the methods used for culling cows from the breeding herd. Most of these cows were culled for reproductive problems. Many of the youngest cows (the two year olds in experiment 1 and most of the three year olds in experiment 2) had failed to produce a single calf. The mature cows had all produced at least three calves in succession during their lifetime. Lesser *et al.* (1973) identified a similar problem in cross sectional experiments relating fat free body weights to age in rats. Rats with low fat free body weights lived longer and represented a majority of the population in old age. From a practical beef production point of view it did not matter if "reproductive competency" had any effect at all. Since economics dictate that each cow must produce a calf each year, the cows used here were probably representative of the cows that would be culled from most Western Canadian herds.

In the boneless beef trade, where many mature carcasses go, the effect of increasing age on the carcass value would be determined by a small percentage increase in bone (waste) due to the lower muscle: bone ratios. For other purposes, beef cuts from cattle with thick, fleshy muscles may be more suitable than those from cattle with thin, rangey muscles. In this way, carcass shape, in addition to carcass

composition and weight, affects the carcass value (Yeates, 1952). Judges of carcasses and live animals have long attempted to include "conformation" in the judging criteria. The analysis of carcass weight or rib eye areas with length as a covariate may be used as an objective measure of conformation that equates good conformation with a high muscle: bone ratio. An advantage of such a system is that it is non-destructive and in no way lowers the value of the carcass.

While carcass maturity is an extremely important factor in determining carcass value under the Canadian grading system, it is based on a visual appraisal of the skeleton and so cannot be measured on the live animal. Carcass maturity can be estimated if chronological age is known. For the cows used in these experiments, maturity division, as determined by the government grader, and the chronological age were known for each cow. It was difficult to make an accurate assesment of the system using cross sectional data of this sort. The age at which a cow entered a particular maturity division and the age at which she would have entered the next maturity division are unknown (rate of maturation). Without these "transition ages", far more observations would have been needed to accurately determine the relationship between chronological age and carcass maturity (maturity based on skeletal ossification). The following observations were made:

At three years of age most cows graded youthful, although a

few fell in the intermediate category. At four years of age there was a split between the youthful and intermediate classifications, with over half being intermediate. At five years of age most cows were of intermediate maturity but a few were classified as mature. All cows six or more years of age fell into the mature category.

For the producer, cow feeding may often prove to be profitable. Cow age is important here. After conducting an economic analysis of the data from experiment 1, it was concluded that only for cows 5 years of age or less was the increase in carcass value worth more than the cost of feeding in the spring of 1980. While a different set of economic conditions could have made these mature cows more valuable as feedlot animals, it appears unlikely that they would outperform the younger cows in this respect. For cow-calf producers, feeding cull cows before slaughter can often be worked into the existing operation as a sideline to increase the value of the cows sold and to better utilize labour in the period following the fall pregnancy check and prior to spring calving. For the industry as a whole, cow feeding can increase the total supply of beef available without any increase in the size of the beef herd. In Alberta, in 1979, 22,771 carcasses graded D5 and 2,097 carcasses graded C2 (Agriculture Canada, 1979). If grain feeding could have been used to add 50 kg to each of these carcasses, the total carcass weight would have been increased by 1,243,400 kg. This means not only heavier

carcasses but more valuable carcasses with an optimum level of finish and a moderate increase in muscle mass. The final result would be more beef for sale.

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